JUNIOR GENERAL SCIENCE

DANIEL RUSSELL HODGDON

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BY

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WITH AN INTRODUCTION
BY
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Commissioner of Education
State of New Jersey

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A 2

TO

MY STUDENTS

WHO HAVE GIVEN ME VALUABLE ASSISTANCE

IN THE SPIRIT OF FELLOW WORKERS

WITH WHOM MANY LESSONS HAVE BEEN LEARNED

AND

WITH WHOM MANY PLEASANT HOURS HAVE BEEN SPENT

BOTH INSIDE AND OUTSIDE THE CLASS ROOM

THIS BOOK IS DEDICATED

INTRODUCTION

WHEN I was a boy in a country school a forward-looking teacher placed in the school a textbook entitled "Natural Philosophy."

That book was a storehouse of information. It described in simple language many examples of natural phenomena. It was an introduction to the science of interesting everyday things. As a result of the study or reading of this book many of us began to understand in a new way the world about us.

It contained little mathematics. Such mathematical problems as it did present could be solved by arithmetic and were not so difficult as to detract from the interest of the book.

In the intervening years I have always regarded that book as most valuable. I have heard one of our most distinguished physicists say that books of this kind do more to popularize science for the masses of the people than any similar books of severer scientific pretension.

Since that time applied science has been greatly extended, so that it touches our common lives at more points than formerly.

Mr. Daniel R. Hodgdon, a science teacher of experience, has prepared a book similar to the one I have briefly described, as a contribution to the field of general science as it exists to-day. It is simple, it has little mathematics, it is free from technicalities, it makes no pretense of being exhaustive, and it is, moreover, very interesting.

The kind of information that this book and similar books contain should be in the possession of all our young people. This kind of information causes them to understand the reason for many of the common

facts in the world about them; it affords valuable mental discipline and stimulates the imagination all unconsciously to the pupil. It makes pupils more intelligent in the common objective phenomena of life and affords guidance in everyday affairs.

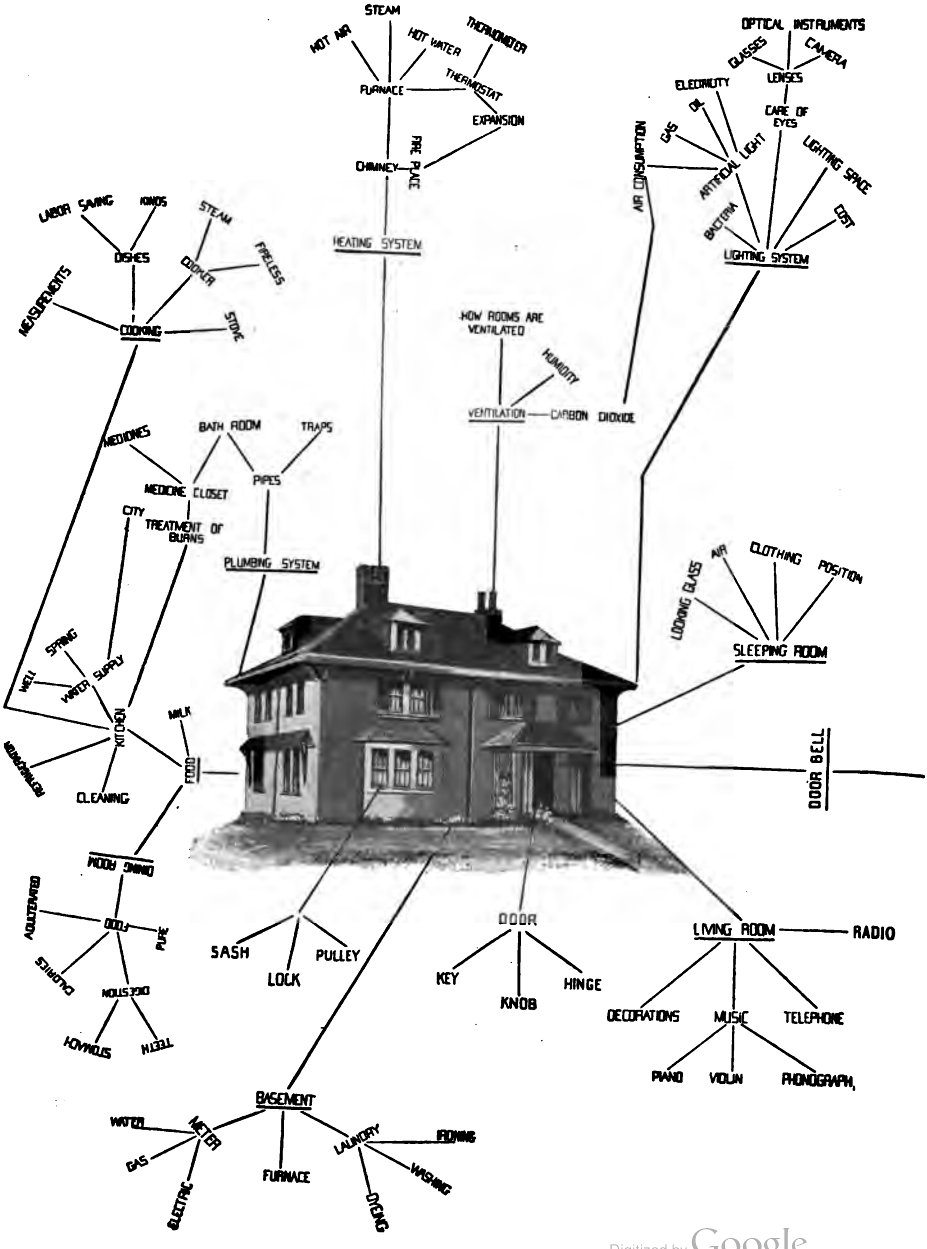
CALVIN N. KENDALL,
Commissioner of Education,
State of New Jersey

PREFACE

DURING recent years there has been much discussion of methods for the teaching of General Science, and of the subject matter to be included in an elementary book and the best arrangement of this subject matter.

After years of experience in teaching General Science from many outlines and by many methods, the author has become convinced that there is but one satisfactory way. That General Science as an elementary course should prepare students merely for further pursuit of the various sciences included in this subject is an unprogressive idea. The proper basis for the teaching of this subject is the environment of the student. From this point of view the textbook should so emphasize the fundamental facts and phenomena of nature that they become of vital interest to the student. Scientifically presented, they should be easily comprehended, and above all, should be useful both in the future study of science and in everyday life.

For several years the author has endeavored to discover, through tests and experiments, what methods of presenting the subject best arrest the attention and hold the interest of the elementary student. He has continually urged his classes to ask questions about everything they see of which they desire an explanation. By this method were gathered over one thousand questions differing much in type. Most of the questions centered about the home. Accordingly the author one day drew on the blackboard a large diagram of a house. Each class has developed this diagrammatical outline from the questions asked, the observations made, and the material nearest at hand. The use of the diagram led the author to use the home as the center around which the subject matter of the book could be built. With this idea as a basis a topic might be developed along physical, chemical, biological, geographical and other lines — a result which at once calls into play a great variety of facts and experiences which have, nevertheless, a common


STEAM
HOT AIR
HOT WATER
THERMOMETER
THERMOSTAT
FURNACE
EXPANSION
CHIMNEY
FIRE PLACE
HEATING SYSTEM
OPTICAL INSTRUMENTS
GLASSES
CAMERA
LENSES
ELECTRICITY
OIL
CARE OF EYES
GAS
AIR CONSUMPTION
ARTIFICIAL LIGHT
LIGHTING SPACE
BACTERIA
COST
LIGHTING SYSTEM
LABOR SAVING
KINDS
STEAM
DISHES
COOKER
FIRELESS
MEASUREMENTS
COOKING
STOVE
HOW ROOMS ARE VENTILATED
HUMIDITY
VENTILATION
CARBON DIOXIDE
MEDICINES
BATH ROOM
TRAPS
PIPES
MEDICINE CLOSET
CITY
TREATMENT OF BURNS
PLUMBING SYSTEM
AIR
CLOTHING
POSITION
LOOKING GLASS
SLEEPING ROOM
SPRING
WELL
WATER SUPPLY
KITCHEN
MILK
FOOD
REFRIGERATION
CLEANING
DOOR BELL
DINING ROOM
ADULTERATED
FOOD
PURE
CALORIES
DIGESTION
STOMACH
TEETH
SASH
LOCK
PULLEY
DOOR
KEY
KNOB
HINGE
LIVING ROOM
RADIO
DECORATIONS
MUSIC
TELEPHONE
PIANO
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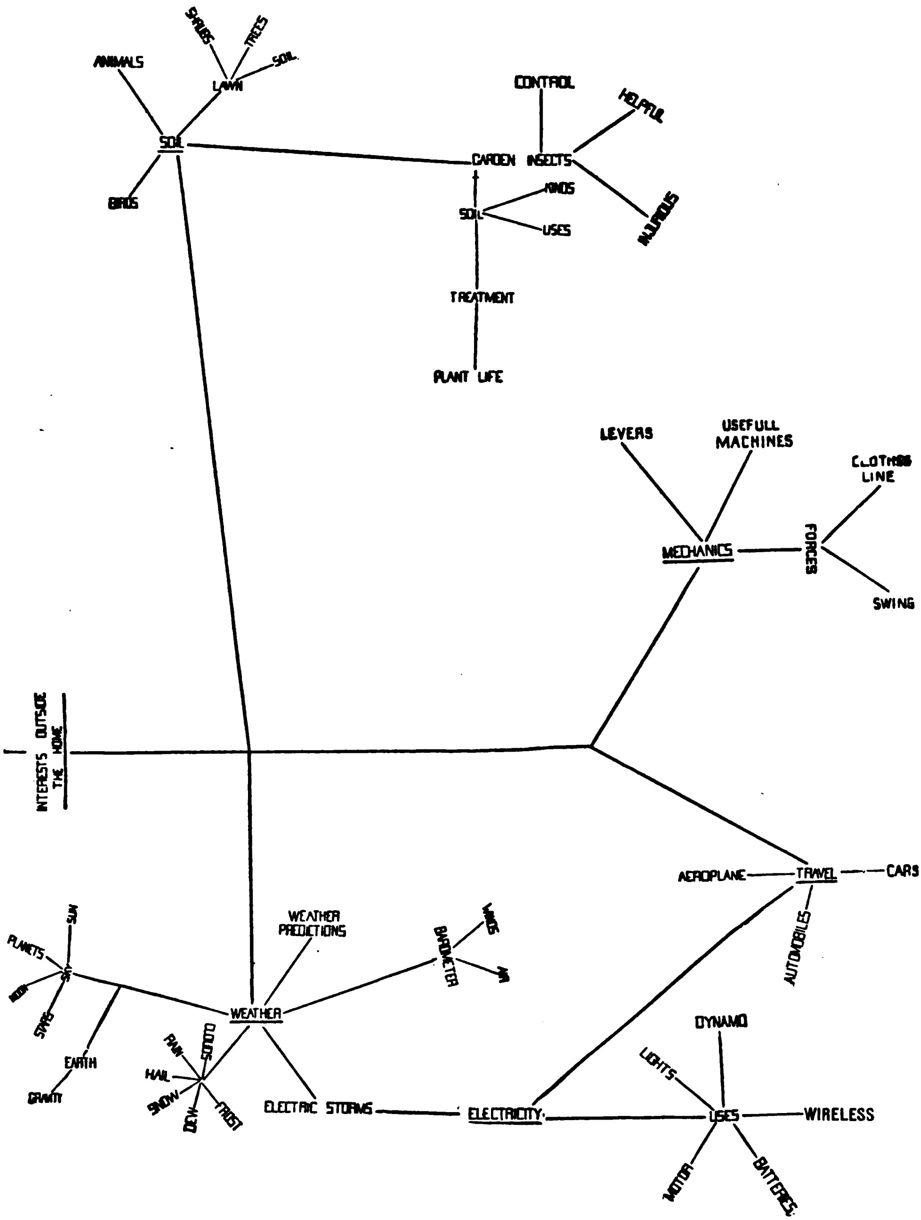
INTERESTS OUTSIDE THE HOME
SOIL
ANIMALS
SHRUBS
TREES
SOIL
LAWN
BIRDS
GARDEN
INSECTS
CONTROL
HELPFUL
INJURIOUS
KINDS
SOIL
USES
TREATMENT
PLANT LIFE
MECHANICS
LEVERS
USEFULL MACHINES
FORCES
CLOTHES LINE
SWING
TRAVEL
AEROPLANE
CARS
AUTOMOBILES
WEATHER
WEATHER PREDICTIONS
BAROMETER
WINDS
AIR
SUN
PLANETS
STARS
EARTH
CLOUDS
RAIN
HAIL
SNOW
DEW
FROST
ELECTRIC STORMS
ELECTRICITY
USES
DYNAMO
LIGHTS
WIRELESS
MOTOR
BATTERIES

basis in the home. In progressing from one part of the house to another it was necessary that certain fundamental facts be discussed and digested before taking up others; that is, a certain logical progress of development must be maintained. Furthermore, the sequence of chapters is such that the thought developed in each leads easily and logically into the subject of the following. For example, on page 182, Chapter IX, is a treatment of germs and disease which concludes with a discussion of germicides and a statement that light is the most effective of all germicides. The following Chapter takes up the subject of Light.

Some lessons have been planned to develop interest, whereas others are essentially fact lessons. Also, numerous questions are based upon these two types. Moreover, the author has so framed the questions that they will develop free and informal discussion among the members of the class. In his classes students are given ten minutes of each period within which to tell of their observations regarding phenomena and to venture explanations. It is a curious fact that from year to year many of the same observations and questions have been made and asked by class after class. A good plan is to let one student perform the experiment while the whole class enter into the discussion. Definite assignments to students who are especially interested in certain phases of the subject — such as the explanation of wireless apparatus, etc. — are always instructive and worth while provided a general discussion follows. The teacher will do well to encourage his students to start interesting discussions by their making statements somewhat after this manner: "This morning while coming to school I observed that smoke was sinking toward the ground. I do not know the reason for this but should like to have it explained." Or a girl student might say, "Last evening while helping mother wash the dishes I noticed that two of the glasses stuck together. What was the reason for this?" This method of socializing the recitation should prove a powerful stimulant for sharpening the students' powers of observation. If, after these lessons have been pursued for a few weeks, the students begin to tell the teacher that they are enjoying the course in science more than almost any other of their courses, he should not be surprised, for has not a great portion of the course been drawn from the students' own experiences of everyday life.

That boys and girls have graduated from school with little

knowledge of the interesting facts of their environment, all too little ability to understand the simple phenomena of nature, and little if any desire to examine into the causes of these phenomena, is a regrettable fact. If the work in General Science, which has found such universal favor with the young pupils in the writer's elementary courses, shall serve to introduce the pupil to a better understanding of the simple facts and fundamental principles of natural laws, and shall also be successful in cultivating in the pupil a desire to know more about his environment, this course will have found a very definite place for itself in the curriculum of the public school.

The enlightened and forward-looking teacher persuades the pupils to go to the dictionary when they are not sure of the pronunciation of a word; and when an unfamiliar word is undefined in the text. Now and then in this book the author has omitted a definition that may seem needed, his purpose being expressly to send the pupils to the dictionaries. The dictionary habit carries one far on the road to knowledge and to the power that lies in felicity of expression.

By means of the copious Index this volume may readily be used as a handy cyclopedia of information on the whys and wherefores of the multitude of familiar (and generally unexplained) phenomena in and about the home.

DANIEL R. HODGDON.

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The author wishes to give recognition to the following members of the faculty and student body of the State Normal School, Newark, N. J.: To Miss Grace Engels, teacher, who drew Fig. 37; to Miss F. M. Egnor, who drew Fig. 92; to Miss Anna Balling, who has often given the author much valuable assistance; to Miss Sophie Eyer and to Miss Ruth P. Kennedy, who have given great assistance by drawing diagrams and doing other valuable work.

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The author wishes to acknowledge the many courtesies of the following, who have very kindly furnished cuts:

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TABLE OF CONTENTS

CHAPTER V

CHAPTER VI

CHAPTER VII

CHAPTER XII

CHAPTER XIII

CHAPTER XIV

APPENDIX

JUNIOR GENERAL SCIENCE

CHAPTER I

ATMOSPHERIC MOISTURE AND EVAPORATION

EVAPORATION

How Moisture Gets into the Atmosphere.—Wet thoroughly with water, yet not so as to drip, a piece of cheesecloth about two feet square and hang the cloth on a T-shaped stick about three feet long. Balance the stick on a prism, or cylindrical object such as a piece of crayon or pencil (see Fig. 1).

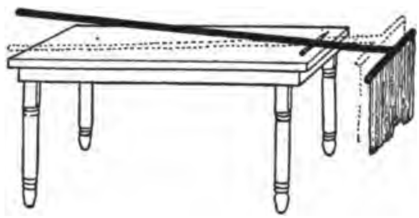


FIG. 1.

Does the stick stay balanced? Why?

Where does the water go?

Why do we not see the water which has passed off into the air?

Evaporation is the chief method of supplying the atmosphere with moisture. A liquid is said to evaporate when it changes into a gas and is absorbed by the atmosphere. If a wet cloth freezes, it will dry on the line as the ice evaporates. That is, the ice will change from a solid directly into a vapor. This change is part of a process called **sublimation.**

Water evaporates more rapidly in some places than in others. It is estimated that in the course of a year a body of water in Mississippi would be lowered fifty inches by evaporation; in New York about forty inches; at Denver seventy; at Lake Superior twenty; and in southern Arizona about one hundred inches.

Water will not evaporate so quickly on some days as on others. Though few can give the reason, we all know, from experience, that there are "good" and "bad" days for drying clothes. Some days the light wind steals the moisture from the clothes with gratifying rapidity; another time the air is so full of vapor that it can receive no more, and the "drying" process is at a standstill.

A sponge or flannel cloth, or even a domino of sugar, if held over a basin of water so that it just touches, will soak up water until it can hold no more. The air, however, receives the vapor instead of soaking it up. A sponge or cloth or piece of sugar can always take up a certain quantity of water and no more, and always the same amount. Not so with the air. The amount of moisture that the air can take up depends upon its temperature. Warm air will hold more moisture than cold air.

To Show that Warm Air Holds More Moisture than Cold Air.—Take a large flask, and put into it just enough water to make a thin film on the inner walls when shaken. Now warm the flask, never bringing its temperature to the boiling point. When the water film has disappeared, tightly cork the flask and allow it to cool.

Notice that when the flask is hot no moisture can be seen. After the flask is corked no moisture can enter; but as soon as the flask has cooled the moisture is seen collecting on the inner walls. As long as the air in the flask is hot it can hold much moisture, but when the air cools it can not hold so much.

Effects of Wind on Evaporation.—Clothes dry or mud puddles dry up more quickly on a windy day than on a still day. When the air around a wet object is full of water, it will not receive more water from that object; but let the wind move the moist air aside, and the wet object will release more of its moisture to any dry air that goes by. Winds aid evaporation.

Other Ways in which Moisture Gets into the Atmosphere.—All animals exhale water vapor. A person will give off to the atmosphere each day, by respiration and perspiration, from a pint to three quarts of water, according to the amount of exercise taken. Plants give off much moisture. For example, a sunflower will give off from a pint to a quart of water each day, or about 125 pounds of water during the season.

An average oak tree gives off about 200 gallons of water during a dry summer day. A birch tree with about 200,000 leaves has been estimated to give off from 700 to 900 pounds of water, or about 125 gal-

lons on a hot day, and only about two or three gallons on a cool day. In hot weather an acre of grass will yield enough water to the atmosphere to equal its own weight, or about 1600 gallons a day, equivalent to more than 50 barrels, or about 6½ tons of water. An average sized city lot covered with grass will give to the atmosphere about 10 barrels of water on a hot day.

Evaporation from the Soil.—Water evaporates from the soil, but more water evaporates from soil which is full of tiny openings (fine porous soil) since the water rises to the surface more rapidly in such soil than in soil which is very loosely packed together.

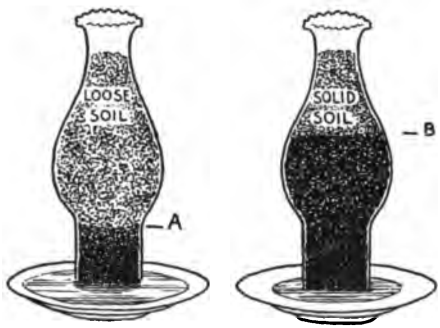


Fig. 2.

A farmer cultivates his garden frequently during warm weather so as to form a loose mulch an inch or so thick. Because of the steadier evaporation thus caused, the moisture in the soil rises more freely to the plant roots, which absorb most of it. This process is called "dry farming." Rolling a field or lawn checks evaporation by packing the soil and making it less porous, with fewer spaces for the water to rise between the dirt particles.

To show that water does not rise as quickly through loose fine soil, fill two lamp chimneys with soil of that character, one chimney loosely filled, particularly the two inches near the top; the other chimney snugly packed. Place both chimneys in a basin of water (Fig. 2).

Questions

1. What is meant by "clothes on the line freeze dry"?

2. Why will water evaporate from a lake in Arizona more quickly than in Connecticut?

3. What is wrong with the idea that heat dries up water?

4. Why do clothes dry better on a warm day than on a cold day; on a dry than on a damp day; on a windy day than on a still day?

5. Why are forests important to the water supply of a country?

6. What effects do the trees and the well-kept parks in a city have on the atmosphere?

7. In setting out plants, why should we take care to pack the soil around the roots, but to leave the soil loosely packed about an inch from the surface?

8. Why does a farmer cultivate his garden shortly after a shower?

9. Why are fruits and vegetables spread out in thin layers while drying? What is dehydration?

EFFECTS OF EVAPORATION

Experiments to Show Some Effects of Evaporation.—Arrange in a vertical position two thermometers with similar scales. Attach to one bulb a piece of cheesecloth or wick (see Fig. 3). Have the cloth extend into a small bottle of water. The thermometer to which the cloth has been fastened is a "wet" thermometer because water is rising in the cloth and evaporating from the bulb. The other thermometer is a "dry" thermometer. How many degrees cooler does the wet thermometer become than the dry thermometer? Show how this experiment proves that heat is absorbed when water evaporates.

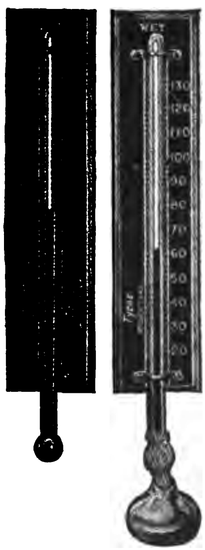


FIG. 3.—Why does the wet thermometer read "lower" than the dry?

Wet one hand in warm water and let the other hand remain dry. Note the contrast in temperatures, and explain.

Issuing from a warm bath, we soon feel cold unless the body is dried instead of letting the moisture evaporate. If the evaporation is slow, not so much body heat is absorbed in evaporation at any one time, but if the evaporation is rapid, a great deal of body heat is absorbed.

This may be easily shown by placing a small amount of ether in a watch glass and placing the watch glass on a drop of water on a cork (Fig. 4). A thin film of water will form on the under side of the glass. Blow through a piece of glass tubing directly on the ether.

Why will blowing on the ether make it evaporate more quickly?

Why does the thin film of water turn into ice and freeze the watch glass to the cork?

Why would not the thin film of water turn to ice if the ether were allowed to evaporate slowly?

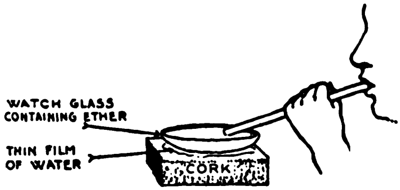


FIG. 4.

Manufacture of Ice. — This principle of evaporation is used commercially for the manufacture of ice. Liquid ammonia,* when evaporating, consumes large quantities of heat. If the vapor or gas from the evaporation is put under great pressure, it will change back to liquid.

An ice manufacturing plant (Fig. 5), has a compressor, *B*; and cooling coils, *C*, over which cold water is run. Gaseous ammonia is made to pass through the compressor which, by pressure, changes it into a liquid, which is then forced through the cooling coils, *C*. Thus cooled, the liquid ammonia is run through pipes which are surrounded with brine. In this brine are rectangular cans of water, *G*. The ammonia liquid which enters the brine-surrounded pipes at *E*, changes by evapora-

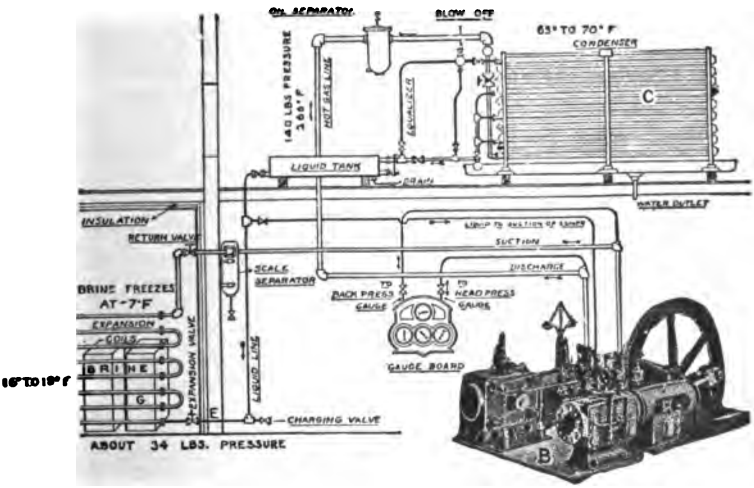


FIG. 5.

* *Not* the household "aqua ammonia."

tion from a liquid to a gas, but in order to change into a gas it requires a large amount of heat. It gets this heat from the brine, which in turn removes heat enough from the water in the rectangular cans to freeze the water, making the familiar rectangular cakes of ice.

Fig. 6 shows a refrigerator for home use. *Instead of ammonia gas,* sulphur dioxide gas is used.

Fig. 6.

Fig. 7.

What is the motor *A* used for?
Why is the compressor *B* necessary?
Why are the coils at *C* called the cooling coils?
Why are the coils in the ice chamber called the refrigerating coils?
What must be done to the liquid sulphur dioxide in order to cool the ice box?
What must be done to the gas in the refrigerating coils before it can be used again?

Iceless Coolers.—The principle of evaporation, used in keeping food and water cool by the natives of tropical countries, is used to-day

by people of every country by making a container of porous material (Fig. 7).

Dipped in water for a few moments every day or two the porous walls of the container become saturated with the water. The water evaporates from the pores of the container if placed where there is a good circulation of air. Evaporation, as we have learned, requires heat, and much of the heat comes from the contents of the container; that is, they are kept cool.

Inexpensive Iceless Refrigerators.—In some parts of the country refrigerators are made by covering a frame of wood with burlap, Canton flannel, or duck.

Of these covering materials duck is by far the best. A number of flannel wicks are sewed to the covering material and the other ends of the wicks arranged to rest in a pan of water on the top of the frame. Shelves are built into the frame for holding food supplies. The water from the pan soaks into the covering material through the wicks. As the water evaporates from the covering material, large quantities of heat are removed, keeping the temperature inside the refrigerator sometimes as low as 50° F.

Relation of Evaporation to Life.—So cooling is perspiration that this process is a protection of the body from high temperature. As the surrounding temperature rises, the amount of perspiration increases, and the body is able to maintain, for a time, its normal standard of health at an incredibly high degree of heat.

Strong, healthy men have been able to remain for some time in rooms whose temperature was as high as 48° above the boiling point of water (212° F.) without any marked rise of bodily temperature. Nor was there any severe discomfort, the temperature of the body being kept down solely by the evaporation of perspiration from the skin. But the air in the rooms must be kept dry, and capable of taking up moisture.

The body generates much heat during the process of changing food into substances that it can use. Much of this heat must be removed. Moisture comes out of our pores and evaporates from the body. If the moisture did not evaporate there would be no cooling process. If we are hot, we fan ourselves. The fan, like the breezes, causes drier air to come in contact with our faces, to absorb the moisture of perspiration, and waft it away as vapor.

If anything prevents the evaporation of moisture from the body, heat accumulates and the temperature rises. If a person does not get

relief before his temperature reaches 106° or above, death will soon follow.

The doctor tries to cool the body by evaporation. If he is not able to get perspiration started, he gives the patient an ice bath. This, of course, removes much of the heat, but drives the blood from the surface. The patient is then removed from the ice bath and placed in hot blankets. The sudden change stimulates the sweat glands, and perspiration starts, followed by evaporation.

Nature has provided us with a well-balanced regulator to control the body, a regulator known to us as the **nervous system.** By this regulator, if the body is getting too warm, more blood is brought up to the skin in order that the extra heat may pass off into the outside air. If the body is getting too cold, this regulator causes the little channels in which the blood circulates to contract, so that the warm blood moves less rapidly from the deeper parts of the body, where the heat necessary to life can be maintained. This same regulator causes the perspiration from the pores of the skin when the body becomes hot. The evaporation of this sweat cools the body.

The range of health is confined between $97\frac{1}{2}°$ and $99\frac{1}{2}°$ Fahrenheit of bodily temperature. A bodily temperature below $97\frac{1}{2}°$ F. portends death by evaporation or by a discontinuance of the heat-producing process within the body. A temperature above $99\frac{1}{2}°$ F. portends death by an excess of heat not removed by evaporation.

Sunstrokes, fevers, and colds are conditions due to failure of the pores of the body to act normally. A person will often take a hot bath and drink hot lemonade to bring out perspiration which when evaporating will relieve the body of much heat.

Why We Feel Chilly after Coming Out of a Crowded Theater.—When there are a great many people in a room, an excess of moisture results from respiration and perspiration, and the air of the room can no longer take away the moisture from the body. A person emerging from such a room to the drier outside air gives up the moisture which has been collecting on the body. This takes away a great deal of heat, and thus often causes a chill.

Wearing of Clothes.—The wearing of loose, porous clothing facilitates perspiration. People should wear medium-weight underclothing throughout winter seasons. If heavy underclothing is worn and the person spends most of the day indoors where the temperature is at

summer heat, moisture will collect on the body, as evaporation does not take place freely through the too heavy underwear. Heavy wraps and fur coats should be worn only during unusual exposure, as in driving or motoring.

Questions on Effects of Evaporation

1. Why does sprinkling the lawns and streets on a hot day cool the surrounding atmosphere?
2. Why is it so much cooler after a thunder shower?
3. Why do we feel cold in a draft?
4. The air is as warm when we are riding as it is when we are standing on the ground. Why do we feel cooler riding?
5. In warm regions porous earthen vessels containing the drinking water are placed outdoors. The outer surface is always moist with a film of water. Why is the water within kept cool?
6. Why should we be careful that our clothes are dry and "aired" before putting them on?
7. Which will be cooler, a glass of water or a bottle of water standing on the table? Why?
8. Why should extra wraps be provided for a person who has been in a crowded hall?
9. Why will a hot bath in summer keep a person cool longer than a cold bath?
10. Why do people place a wet cloth over butter jars in summer?
11. Why do we get cold if we sit in a draft?
12. Why did the little boy die who had his body painted with gold paint to represent an angel?
13. Why is a hunter able to tell the direction of the wind by wetting his finger at his mouth and holding it high above his head?
14. Would the man who kept a wet cloth over his gas meter be able to get more gas for his money?

MOISTURE IN THE ATMOSPHERE

Value of Moisture in the Atmosphere.—Water vapor permeates our wonderful air ocean. If moisture were absent, not only would all green things wither for lack of it, but the sun's heat would have a scorching fierceness beyond conception; for the mists, clouds, or other moisture in the air temper its rays. They act in another way also. Their presence softens the sunlight. Acting as a screen, they temper the heat and diffuse the light.

Again, the "night work" of moisture is very important. During the day the earth gathers heat from the sun's rays as they beat upon it. At sundown the stored-up heat begins to radiate into space. The vapor in the air prevents this heat from radiating too rapidly. But for this blanket of moisture to check the heat, the suddenness of the chill would be extreme.

Cloudy nights are warmer than clear nights, for the cloud-blanket, by keeping the heat near the earth, lessens the radiation. On clear nights the earth loses its heat more rapidly.

Relation of Evaporation to Bodily Comfort.—In deserts, where the relative humidity is small, evaporation goes on very rapidly. Wherever there is abundant moisture on surfaces, the relative humidity is great, and little or no evaporation can take place. Such conditions obtain in forests of the tropical zones. The same conditions prevail in temperate zones where there is a meagre rainfall in summer time. This lack of evaporation causes discomfort in humid, close, or muggy weather. At such times the heat becomes oppressive, we perspire easily, and are uncomfortable because of the lessened evaporation from the surface of the body into humid air.

On clear, dry days we feel more comfortable because evaporation from the skin removes the perspiration, the percentage of relative humidity being so low that the air can more rapidly evaporate the surface moisture. It is because of this that the temperature of 90° to 100°F. or more in Arizona is not so uncomfortable as are the same temperatures in the Mississippi Valley or near the Atlantic Coast where the relative humidity is greater.

Humidity.—To most of us "humidity" is an indefinite term. We know that when the humidity is high there is much moisture in the air;

and little when it is low; but the significance and importance of all this is hazy in our minds. Few persons take any note of "humidity," particularly as affecting the health. They realize that "muggy weather," especially in summer, is uncomfortable and depressing, but they do not know why "humidity" so affects them. Yet humidity must be taken into account when planning for healthful temperatures in the home, the school and elsewhere. The lack of humidity, or moisture, causes discomfort from catarrh, colds, and other diseases of the mucous membrane. If we had the proper percentage of humidity in our homes throughout the winter, we should be more healthy and comfortable, besides saving from 12½% to 25% of our total cost of heating.

Health authorities state that in the average home, heated by steam or hot water to a temperature of 72° F., the relative humidity averages but 28%, while with hot air furnaces the average is as low as 24%. Even in the great desert wastes the humidity averages 30%. Now, if a person passes from so dry an "indoor climate" into outdoor air having a percentage of humidity of 70% or more, the violent change seriously affects the mucous membrane of the air passages, causing bronchitis, pneumonia, and kindred ills.

Humidity is just as variable as temperature. The dews, and the rains, as well as the winds depend upon fluctuations of the heat in the air. The percentage of humidity may range from "dry" to **saturation.** Air so full of moisture that it will hold no more, is *saturated* and is 100% humid.

How Humidity is Measured.—There are two ways of expressing humidity. **Absolute humidity** is the amount, *by weight,* of water vapor actually present in the air.

The weight of the water vapor would be 10.4 pounds in a schoolroom 20 feet wide by 30 feet long by 15 feet high if the air were saturated.

Relative humidity is the *proportion* of water vapor actually present in the air compared with the greatest amount it could contain.

Air saturated would have 100%, and perfectly dry air would have 0% relative humidity.

Humidity, Temperature, and Bodily Heat.—Humidity influences the heat of our bodies in two ways. At a given temperature, moist air conducts heat from the skin more readily than dry air. In warm weather the difference in temperature between the body and the air is

so slight that neither moist nor dry air conducts any large amount of heat from the skin, but when the difference of temperature is greater, the effect of humidity in that respect is very marked. Moist air at 65° F. is chilly to one sitting still, while dry air at this temperature is comfortable. When perspiration is operating to maintain the normal temperature of the body, the moisture of the air hinders the escape of heat from the body by retarding the evaporation of the sweat. Therefore, a high percentage of humidity makes us feel warmer on a warm day and cooler on a cool day.

Schoolroom "Deserts."—On the "perfect days" in May and early June, with all windows open, admitting freely the outdoor air, it is interesting to note that the thermometer stands at about 65° to 68° F., and the hygrometer registers about 60% relative humidity. A usual cause for nervousness, or "fidgets," among school children is the dried out, desert-like atmosphere of the schoolroom, the temperature of which, during the winter months, is usually and ill-advisedly kept above 72° F.

The introduction of vapor by opening the windows when permissible, by opening the steam valves, or by means of wet cloths over the radiators, or of pans of water conveniently placed, will almost instantly relieve the tension of a schoolroom full of children.

How We Take Cold.—Constant colds and sore throats testify to the effects on mucous membrane of too high a temperature and too dry an air. Anæmia, debility, and irritability bear witness to their ill effect on the blood and nerves. Too many homes and schools are overheated because of the mistaken notion that this is the way to be comfortable.

The prime cause of colds and sore throats is not exposure to cold, but to the overheated, confined air of rooms, factories, and public meeting places, and to infection therein.

Experiments have shown that for each degree above 65° F. the power of mental concentration diminishes. Contact with cold fresh air, instead of inducing colds, stimulates both the mind and the body.

A steady supply of pure air should be admitted at all times to every occupied room. A piece of board about 8 inches wide and long enough to fit on the bottom sash of a window, in each room, will allow air to enter and rise toward the ceiling if the window is open a little way at the bottom. This fresh air will gradually descend on the occupants, who will thus feel no draft.

Questions

1. Why does the air feel so chilly during a "spring thaw"?

2. What would be the difference between the bodily feeling on a day with humidity 93% and temperature 80° F., and that on a day with humidity 65% and temperature 80° F.?

3. Why put on wraps when leaving the house on a cold day?

4. Why does the furniture come apart in a room where there is little humidity?

5. Why does the atmosphere in New York City feel colder at 10° F. than the atmosphere in Montana at 0° F.?

CHAPTER II

MOISTURE COMING FROM THE ATMOSPHERE

WATER CONDENSING NEAR THE EARTH

Dew.—Put a few pieces of ice in a shiny can half full of water. If there is sufficient moisture in the air of the room (relative humidity of about 60%), fine drops of water begin to form on the can, slowly becoming large drops of dew. The temperature of the can when the dew begins to form is called **dew point.** Dew would collect on all the smooth objects in the room if they were cooled to dew point.

We have learned that cold air will hold less moisture than warm air. As soon as the air of the room (assumed to be warm) comes in contact with the cold can it is cooled, and must yield some of its moisture, because it cannot hold as much water vapor as when warm.

Dew on the Grass.—During the night the ground is cooled by radiation. The air next to the ground is chilled by contact with the cold ground. If this air is moist the moisture will be deposited on the grass, for the same reason that the water was deposited on the can. Dew forms on the grass more quickly than on the wooden sidewalk because the grass cools off faster than the wood.

Frost.—Frost is not often frozen dew. Usually it is frozen water vapor. The temperature of the cold object on which the frost forms, instead of dew, is below 32° F., so that the vapor from the air adheres, frozen, directly to the cold object before it has time to form into drops of water (dew).

Things to Remember about Dew and Frost.—Cloudy nights are dewless. The clouds act as a blanket, keeping the colder air away and retarding the radiation from the ground. Windy nights, also, are dewless. Nor does frost form during a blow. In a wind the moving air does not have time to yield its moisture as either dew or frost.

Dew will form on clear nights, and, if the night is cold, frost.

Very little dew will form on the tops of trees, but a great deal will form on grass. Tell why.

More dew will form on a cool night than on a warm night.

Dew forms readily on faucets, pitchers, cellar walls, grass, and other objects which yield their heat quickly.

Often in the country, frost will form in a hollow, while in the same night there will be no frost on the neighboring higher levels. Tell why.

Farmers often try to prevent damage by frost by building fires in the field or garden, using materials preferably that burn with much smoke. Clouds of smoke lessen radiation. Besides, the air being set in motion in and about the fires, the cold air and warm air mix. In the cranberry regions some growers flood the cranberry bogs with water when frost threatens. Water as such does not spoil the crop if drained off in time.

FIG. 8.

Ice Storm.—A sudden jar may hasten the solidification of a liquid which, although at the freezing point, has not yet turned solid. This happens in cold weather when raindrops or fog particles turn to ice upon contact with objects such as trees, telegraph wires, etc. The resulting smooth coating of ice, called *glazed frost*, often becomes so thick on the branches and wires as to produce the familiar "ice storm."

Hoarfrost or Rime.—Hoarfrost or rime is the white coating of feathery crystals of congealed moisture formed in misty weather when the temperature is freezing.

Fog.—Dust pervades our atmosphere. Smoking volcanoes as well as volcanoes in eruption discharge dust. Some of the dust is salt from the oceans. Commotion on dusty roads, and the winds blowing over them,

all fires which discharge smoke, the pollen of flowering plants, and all things wearing away contribute dust to the atmosphere. More of the dust is in the air over and near cities, and after forest fires. A hazy atmosphere is often but a dusty one—the dust from the roads and fields and bare eroding surfaces.

These dust particles account for the blueness of the clear skies as well as for the wonderful colors of the beautiful sunsets and the dawn. Except for them the sky, even in daytime, would look black. A beam of light across any darkened enclosure discloses myriads of dust particles.

Upon the dust particles in cold currents of air moisture condenses forming drops so minute that they float about in the atmosphere. It might be said that fog is the dew on the dust particles.

Mist.—There are times when the air is permeated with moisture in particles larger than those of fog, and yet not as large as rain drops. When the moisture in the air takes on this aspect we have the familiar *mist*.

Questions

1. Why do people say that "dew falls"?
2. At what time of year do the heaviest dews occur? Why?
3. Why does an electric fan in a store window prevent frost or mist forming on the window?
4. At what time of year is a hazy atmosphere most frequent? Why?
5. When will "hoar frost" form?
6. What causes fog to appear to "lift"?
7. Why do farmers feel no concern about frost on a cloudy night? On a windy night?
8. What makes ice pitchers, cold water pipes, etc., "sweat"?
9. When ice appears to "steam," what is the cause?
10. Why is there often a fog around an iceberg?
11. Why do eyeglasses become covered with moisture when brought into a warm room from a cold atmosphere?

FORMS OF WATER IN THE ATMOSPHERE

Clouds.—Fog or mist may be called nothing more than a cloud resting on the earth. Moist warm air rising high above the surface of the earth cools off as it reaches the higher levels. The moisture then condenses into small water particles in the air. Sometimes we see small clouds like large snowballs forming in the air. These *clouds* are usually at the top of some rising column of warm moist air which has reached a stratum of cold air.

Kinds of Clouds.—There are many forms of clouds, the most common being Stratus, Cumulus, Nimbus, and Cirrus.

The subject matter of this section in fine print is to be studied by observation. Compare these old sayings with that which actually happens. If any of the weather forecasts prove true, try to tell why.

Fig. 9.—Stratus.

Stratus.—One-fourth to three-fourths of a mile high. A haze-like cloud which consists of fog in a horizontal stratum.

A sky covered with clouds does not betoken a storm if the latter are high, and of no great density, and the air is still, the barometer at the same time being high. Rain falling under such circumstances is generally light and soon over.

Cumulus.—One-half mile to 2 miles high. Woolpack clouds. Thick clouds whose summits are domes with protuberances, but whose bases are flat. When the cloud is opposite the sun the surfaces usually seen by the observer are more brilliant than the edges of the protuberances. When the illumination comes from the side this cloud shows a strong dark shadow. On the sunny side of the sky, however, it appears

dark with white edges. The true Cumulus shows a sharp border above and below.

Well-defined cumulus clouds, forming a few hours after sunrise, increasing toward the middle of the day, and decreasing toward evening, are indicative of settled weather. If, instead of subsiding in the evening, leaving the sky clear, they keep increasing, they are indicative of wet.

FIG. 10.—Cumulus.

Cumulus clouds, smaller at sunset than at noon, herald fair weather.

Cumulus clouds heaped up during a strong wind at sunset presage thunder during the night.

When a heavy cloud comes up in the southwest and seems to settle back again, look out for rain.

FIG. 11.—Nimbus.

Nimbus.—About 1 mile high. Rain clouds. Dense masses of dark, formless clouds with ragged edges from which rain or snow is gen-

erally falling. Through the breaks in these clouds there is almost always seen a high sheet of Cirro- or Alto-stratus. If the mass of Nimbus is thrown up into small patches, or if low fragments of clouds are floating much below the great Nimbus, they may be called Fracto-nimbus or Scud. Light Scud clouds indicate wind.

Clouds flying against the wind indicate rain.

If clouds float at different heights and rates, but generally in opposite directions, expect heavy rain.

FIG. 12.—Cirrus.

Cirrus.—About 5 to 7 miles high. Feather-like clouds high up in the air. Cirrus clouds are usually composed of ice particles. They are often called Mare's Tail.

If cirrus clouds dissolve and appear to vanish, it is an indication of fine weather.

The longer dry weather has lasted the less likely is rain to follow the appearance of cirrus clouds.

If cirrus clouds form in fine weather with a falling barometer, it is always indicative of rain.

When threads of cirrus clouds are brushed back from a westerly direction, expect rain and wind.

If the streaks of cirrus clouds point upward, they indicate rain. If downward, they indicate wind and dry weather.

Cirro-Stratus.—Two to 6 miles high. A fine whitish veil, sometimes quite diffuse, giving a whitish appearance to the sky, and called by many, Cirrus Haze. Sometimes it shows more or less distinct structure,

exhibiting tangled figures. This cloud formation often produces halos around the sun and moon.

FIG. 13.—Cirro-stratus.

When cirrus merge into cirro-stratus, and when cumulus increase toward evening and become lower, expect wet weather.

Cirro-Cumulus.—Three to 6 miles high. A collection of fleecy clouds. Small white balls and wisps without shadows, or with very faint

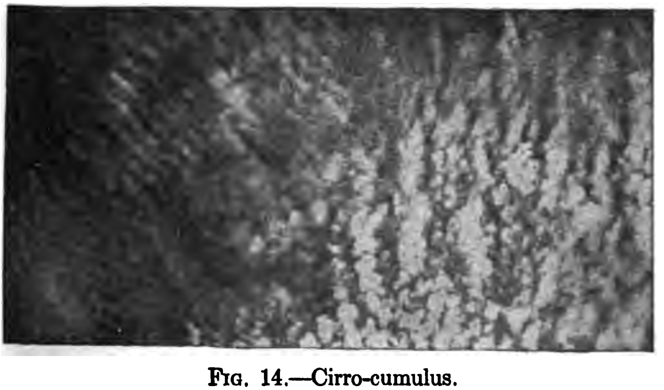


FIG. 14.—Cirro-cumulus.

shadows, which are arranged in groups and often in rows. Many people call this a "mackerel sky."

When cirro-cumulus clouds appear in winter, expect warm and wet weather.

Mackerel clouds in sky,
Expect more wet than dry.

A mackerel sky,
Not twenty-four hours dry.

Mackerel scales and mare's tails,
Make lofty ships carry low sails.

Fracto-stratus.—Fracto-stratus is the true stratus torn by the wind or mountain summits into irregular fragments.

Fracto-cumulus.—These are broken masses of cloud which are continually changing in form. They are caused by the true Cumulus being torn by strong winds into detached parts. Fracto-cumulus clouds present continual changes.

FIG. 15.—Strato-cumulus.

Strato-cumulus.—One-half to 3 miles high. Large balls or rolls of dark clouds which frequently cover the whole sky, especially in winter, and give it at times an undulating appearance. The stratum of Strato-cumulus is usually not very thick. A blue sky often appears in breaks through it. Between this form and the Alto-cumulus all possible gradations are found. It is distinguished from Nimbus by the ball-like or rolled form. It does not tend to bring rain.

Cumulo-nimbus.—One-half to $4\frac{1}{2}$ miles high. Thunder cloud; shower cloud. Heavy masses of clouds rising like mountains. From

their base generally fall local showers of rain or snow and sometimes hail or sleet. The upper edges are either of compact Cumulus-like outline

FIG. 16.—Cumulo-nimbus.

and form massive summits surrounded by delicate false Cirrus, or the edges themselves are drawn out into Cirrus-like elements. This last form is most common in spring showers.

FIG. 17.—Alto-cumulus.

Alto-cumulus.—Two to 4 miles high. Dense, fleecy clouds. Large whitish or grayish balls with shaded portions, grouped in flocks or rows, frequently so close together that their edges meet. The different balls are generally larger and more compact toward the center of the

group, and more delicate and wispy on its edges. They are very frequently arranged in lines in one or two directions.

When a heavy cloud comes up in the southwest, and seems to settle back again, look out for a storm.

Clouds upon hill, if rising, do not bring rain; if falling, rain follows.

FIG. 18.—Alto-stratus.

Alto-stratus.—Three to 5 miles high. With patches of Fracto-nimbus. Thick veil of gray or bluish color exhibiting in the vicinity of the sun and moon a brighter portion. They may produce coronæ without producing halos.

Alto-stratus shows gradual transitions to cirro-stratus. Fracto-nimbus is more popularly known as Scud, and consists of small portions of cloud at a very low level which travel at some speed.

VARIETIES AND HEIGHTS OF CLOUDS

Name.	Description.	Height.
Stratus	Elevated fog, so called	Sea level up to 3,000 ft.
Cumulus	Round, tower-like clouds with round tops and flat bases	4,500 to 6,000 ft.
Cumulo-nimbus		4,500 to 24,000 ft.
Strato-cumulus	Rolls of dark clouds	6,400 ft.
Nimbus	Masses of dark, formless cloud	6,400 ft.
Cirro-cumulus	Fleecy cloud, a "mackerel sky"	10,000 to 21,000 ft.
Cirro-stratus	Fine whitish veil, giving halos around sun and moon	27,000 ft. (average)
Cirrus	Isolated feathery white clouds	27,000 ft. (average).

Cloud Level.	Height in Feet.	Average Speed, Miles per Hour.
Stratus	1,676	19
Cumulus	5,326	24
Alto-cumulus	12,724	34
Cirro-cumulus	21,888	71
Cirrus	29,317	78

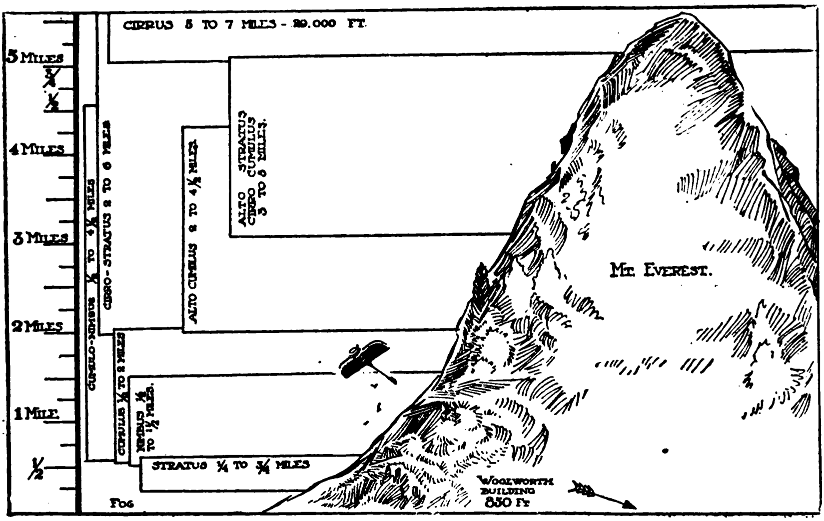


FIG. 19.—What kind of clouds forms nearest the earth? What kind forms farthest from the earth? When would a cloud be called a fog? What kind of clouds has the greatest range of heights? What kind of clouds have you in the sky to-day? Their average height? What do they predict?

WATER CONDENSING HIGH IN THE AIR

Why Air Loses its Moisture.—Cold air cannot retain so great a quantity of invisible vapor as can warm air. At freezing point (32° F.) the air can sustain $\frac{1}{160}$ of its weight of transparant vapor, and for every increase of 20° its retaining capacity is practically doubled. If saturated air is suddenly cooled, some of the moisture will be con-

densed and will fall as rain. The primary cause of rain is the cooling of saturated air.

It has been estimated that in a cubic inch of smoke there are as many as 12,000,000,000 nuclei around which moisture may collect. It is possible that every rain drop is a condensation of moisture around a nucleus. From observations at Pittsburg it was found that from 500 to 1900 tons of dirt per square mile were brought down by rain in one year.

Rain.—Minute drops of water in the atmosphere come together, making larger drops which again join with others, making still larger drops. The air cannot hold up the large drops, and they fall to the ground as a shower of rain.

The chilling of the air which, as we have learned, is the primary cause of rain, may take place either through the rising of air into colder levels, from its encountering a colder current of air, or through its contact with colder surfaces, such as mountains. Some of the heaviest rainfalls take place on mountains near the sea. The air over the ocean gets thoroughly soaked with vapor which, while warmed, it can carry. When its inland movement is opposed by a mountain range the saturated air proceeds upward along the slopes, growing cooler as it goes higher. When the air becomes so cool that it cannot hold the moisture, torrents of rain result.

To give an idea of the amount of water that falls on an acre of ground, the following will be of interest:

0.01 inch of rain equals	62,726 cubic inches or	1.1	tons
0.05	312,636	5.6	
0.10	627,264	11.3	
1.00	6,272,640	113.0	
2.00	12,545,280	226.0	
5.00	31,363,200	565.0	

The rivers come from the clouds, for clouds pour down rain, rain fills the rivers, and the rivers supply the sea. The sea surface goes into the air as vapor, and the vapor becomes clouds; so, whether we start with mountain rivulet or clouds, the circle is complete, for we always return to our starting point.

Every school should have a rain-gauge placed in an exposed position, but well protected from winds.

Hail.—When raindrops become frozen in their passage through the air, they fall as hail. Frequently in a strong wind the water of other raindrops freezes on the surface of the hailstones. This process con-

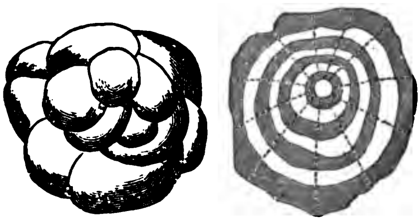


FIG. 20.—Structure of a Hailstone.

tinues until the hailstones becomes so large that by their weight, when they fall to the ground, they often do great damage to crops. Sometimes smaller hailstones adhere to one another, forming a larger knobby one (Fig. 20).

FIG. 21.—Snow-crystals.

Snow.—When condensation occurs at a temperature below freezing the vapor will crystallize and form snowflakes or ice needles of varied forms.

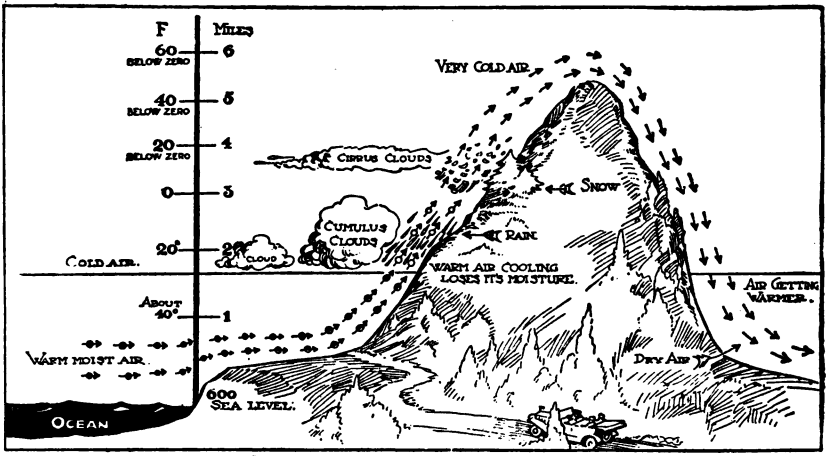


FIG. 22.—The black dots on the arrows represent air laden with moisture. Arrows without dots represent air comparatively free from moisture.

QUESTIONS

1. Why is the air moist coming in from over the ocean?
2. Why will clouds form when air from the ocean sweeps upward along the mountainside?
3. Why do rain and snow fall on the mountain slope?
4. Why is the air so dry on the side of the mountain away from the ocean?
5. Why is the rainfall greater on the ocean side of the mountain than on the farther side and the plains beyond?
6. What effects are produced by the temperature of the air 3 or 4 miles above the earth?
7. What facts do you consider most important in this chapter?

CHAPTER III

THE ATMOSPHERE

ATMOSPHERIC PRESSURE

Close a bottle full of water with a one-hole rubber stopper through which runs a glass tube. If we try to suck the water out of the bottle, we find it is impossible to do so until the stopper is loosened and air allowed to come in contact with the surface of the water.

Our earth is enveloped by an ocean of air, an ocean of gaseous matter a hundredfold deeper than the water oceans. This air is pressing down on us with tremendous weight. It does not crush us because our blood pressure, together with the air in our body, is pressing out as hard as the air is pressing on us.

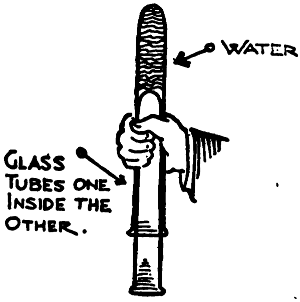


FIG. 23.

Fill a test tube about half full of water. Insert a smaller tube which will just fit inside the larger (Fig. 23). Invert the two. As the water runs out, the inner test tube must rise to fill the space. Why?

Fill a tumbler nearly full of water, place a small sheet of thick paper over the top, and hold it there while you invert the glass. Remove the hand.


FIG. 24.

What is trying to press the paper off?
Why does the paper stay in place?
What keeps the water in the glass?

Press the tip of your pencil under the paper edge just enough to make a slight opening between it and the glass.

Why does the paper come off so quickly?
What other things do you find out from this experiment?

Use of Air Pressure.—The atmospheric pressure is very useful to us. For example, the vacuum cleaner. The motor turns the fan, the fan causes a vacuum within, and the atmospheric pressure forces air in, carrying in with it the dust, lint, etc.

Why must the intake aperture fit closely against the carpet?
Does the fan suck air in from without, or push air from within outwards?

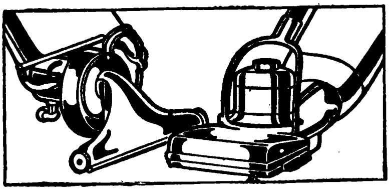


FIG. 25.

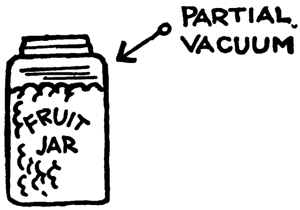


FIG. 26.

Preserving Fruit.—To preserve fruit, air must be kept from contact with the substance of the food, so we heat the can and contents, driving out the air. Without delay the can cover is put on, with a rubber ring to prevent the air getting in. As the can cools off, a partial vacuum results within, and the atmospheric pressure holds the cover on too tightly for the air to get inside.

Pumps.—Air pressure is taken advantage of in the construction of pumps used in wells. The pressure is that of the atmosphere upon the surface of the water in the well, as a result of which pressure some of the water is forced upwards within the submerged pipe of the pump.

As the handle in Fig. 27 (4) moves downward, why is the upper valve closed, and the lower valve opened?

When the handle moves upward, in Fig. 27 (3), why does the upper valve open, and the lower valve close?

Why does the water start to move up through the well?

Why does water go up through the lower valve (Fig. 27, (4)) as the handle moves downward?

What movement of the handle will bring water up to the level where it will run out through the spout?

How does a force pump differ from a lift pump (study 5, Fig. 27)?

What kind of pump is used for tire pumps for automobiles and bicycles?

What is meant by an exhaust pump?

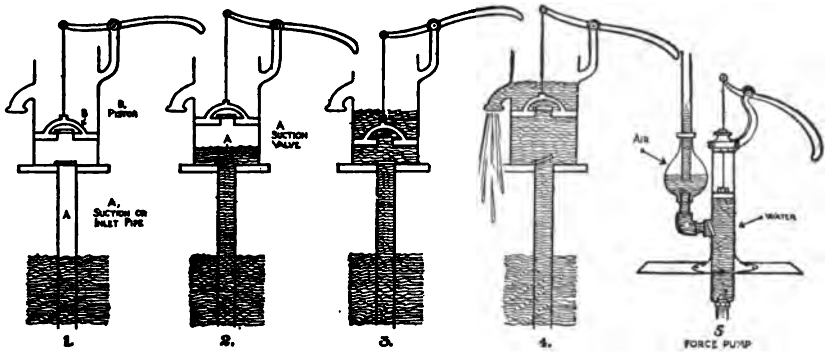


Fig. 27.

Siphon.—Find in the dictionary, and be prepared to tell in class, the definition of *siphon*.

Partly fill a flask with water. Close it with a two-hole rubber stopper. Through one hole insert a glass tube which has been drawn out to a jet, so that the jet is well inside the flask as indicated in Fig. 28. The other end of the tubing is to dip into a jar of water. Insert in the other hole a piece of glass tubing which shall extend just through the stopper. Attach to this a piece of rubber tubing the other end of which is to dip into the water in jar *B* on the floor. When ready, invert the flask, as shown in Fig. 28, and fasten it to a ring stand.

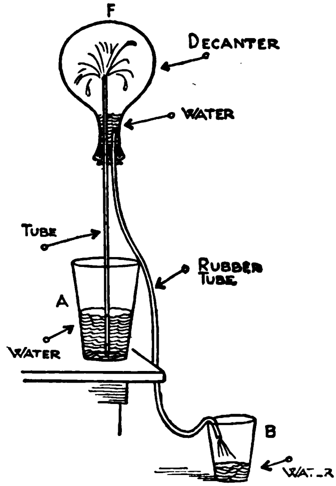


Fig. 28.

As the water runs out of the flask into the jar *B* the air on the surface of the water in the jar *A* will force the water up through the jet in the flask, forming a fountain.

Why does the water run out of flask *F* into jar *B*?

Why will the water in *A* rush up into the flask *F* forming a fountain?

What will happen when the jar B is raised to the same level as A? When raised higher than A?

Arrange a siphon made of a piece of glass tubing as in Fig. 29. Is it necessary to have one arm longer than the other? Why must the siphon be filled with water before it will work? Why will not the water run from the lower end if the finger is pressed against the upper end?

Self-starting Siphon. Among the many useful pieces of apparatus which make use of air pressure is the self-starting siphon.

A self-starting device is shown in Fig. 30, and consists of a bulb (4) sealed into the lower end of the tube (2) and an inner tube (5) sealed

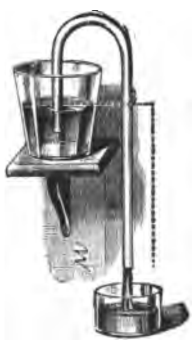


Fig. 29.

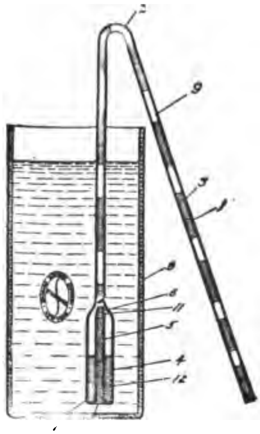


Fig. 30.

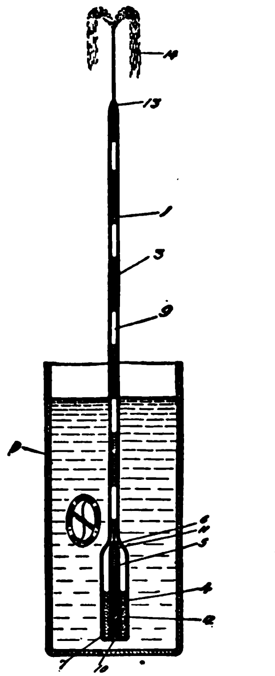


Fig. 31.

into the base of the bulb and reaching into the opening of the bulb at the top. Here the end of the inner tube is somewhat constricted, and its size and position with respect to the top of the bulb are so adjusted that an "air trap" is produced at (6). A small opening (7) is made at the lower part of the bulb.

If the bulb be placed at a considerable depth in the liquid to be siphoned, the liquid enters the bulb through (7) and displaces the air, hich, with the liquid passing through the inner tube (5), rises in a ken column in tube (2) and flows out through the delivery tube.

Self-starting siphons are used in drug stores, chemical laboratories, manufacturing and other establishments where liquids and various solutions are in constant use. In transferring corrosive poisons or valuable liquids they obviate accident or waste.

Air Has Weight.—Place on each end of a stick a flask closed by a rubber stopper, and balance the stick carefully. Remove the stopper from one of the flasks and heat the flask.

The air will expand and some of it will come out. Replace the stopper. The stick will no longer balance. The air in the heated flask does not weigh as much as before. Air has weight.

Another interesting way to show that air has weight is to balance two old electric light bulbs on a stick (vacuum bulbs, not "nitrogen" bulbs). Remove one bulb

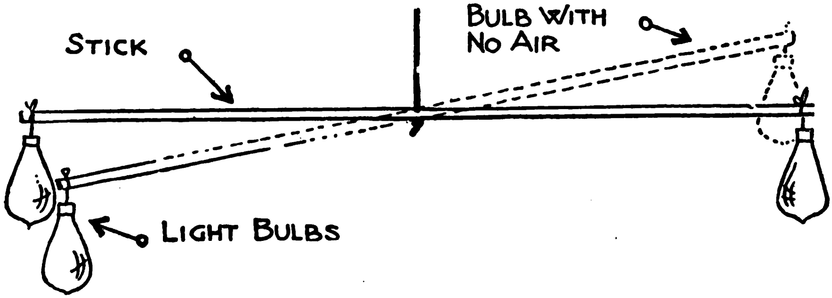


FIG. 32.

and with a blowpipe blow a hole in the side of it. Air will rush in, for the bulb was, as nearly as possible, a complete vacuum. If the bulb is replaced on the stick the two will no longer balance. The air which has rushed into the punctured bulb has weight. Dry air weighs about 1¼ oz. per cu. ft. at sea level, or 13 cu. ft. weigh about 1 lb. Why not use "nitrogen" bulbs in this experiment?

Air exerts pressure equally on all sides of objects.

QUESTIONS

1. What makes water gurgle from a jug? How can the gurgling be prevented?

2. Why have two holes in an oil can? In the stopper of a large ink bottle?

3. Why is it necessary to pierce the rubber of a fruit jar to get the cover off?

4. Why do papers rise in the air after a swiftly moving train?

5. Why is it possible for a fly to walk on the ceiling?

6. Explain the action of a fountain pen filler; self-filling fountain pen.

7. Why will a swinging door open slightly if some one opens quickly a door in another part of the room?

8. Why is it difficult to drink from a small-mouthed bottle?

9. How does the boa-constrictor use atmospheric pressure to swallow its food?

10. About what is the weight of the air in your room?

11. Why will two glasses stick together if one is placed within the other immediately after washing them with hot water?

12. If two books are placed on the table about 2 inches apart, and a sheet of paper placed over them, explain why the paper sinks between the books when one blows between them.

13. Why does the liquid from an atomizer rise in the tube when quick pressure is exerted upon the rubber bulb?

MEASURING ATMOSPHERIC PRESSURE

The Barometer.—The barometer, which only recently has come into popularity, was "invented" nearly three hundred years ago.

Galileo Galilei, an Italian philosopher and mathematician (Born 1564—Died 1642), was asked, toward the end of his life, to explain why water could not be raised in a suction pump to a greater height than 32 feet.

Believing that the pressure of the air does not exceed the pressure of a column of water 32 feet high, he devised an experiment to ascertain the pressure of the air.

His apparatus, which was placed in an inverted position, consisted of a tube, closed at the top, with a very smooth interior in which a closely fitted piston was placed. Weights were applied to this piston to see how much pull was necessary to draw it down. Before his death he advised his pupil, Evangelista Torricelli, to continue these experiments.

Torricelli's decisive experiment ascertained the length of a column of mercury which is sustained by the same cause, whatever it might be,

which supported the column of water. As the weight of mercury is 13.6 times greater than that of water he reasoned that the height of the mercury column should be only about $\frac{1}{13}$ as high as the water column.

Torricelli proved his idea on the subject by taking a glass tube about 3 feet in length, closed at one end, and filled with mercury. Putting his finger on the open end, he inverted this tube in a small bowl, containing mercury, and when he removed his finger, he found that the mercury sank in the tube until its level was about 29 inches above the level of the mercury in the bowl.

Otto von Guericke, in Magdeburg, Germany, invented the water barometer by erecting a long tube reaching from a cistern in the cellar up through the roof of his house. A wooden image was placed within the tube, floating upon the water. On fine days this novel weather-prophet would rise above the roof-top and peep out upon the queer gables of the ancient city, while in foul weather he would retire to the protection of the garret. The accuracy of these uncanny movements attracted the attention of the neighbors. Finally, becoming suspicious of Otto's piety, they accused him of being in league with the devil. So the philosopher removed his "wooden man" and the staid old city was once more at ease.

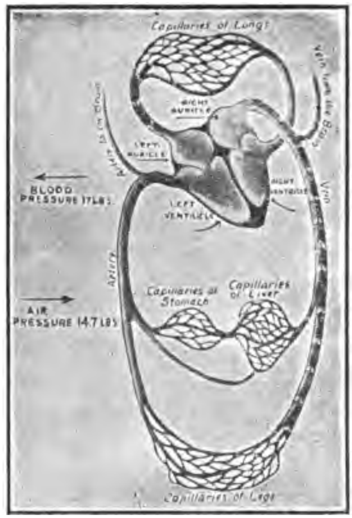


FIG. 33.—How much greater is the blood pressure than the atmospheric pressure? Why is this necessary?

Measuring the Pressure of the Atmosphere.—Take a long open glass tube and put one end in a dish of mercury. Attach an air pump to the upper end of the tube and withdraw the air. The mercury will rise in the tube to about 30 inches at sea level, but no higher. Now a cubic inch of mercury weighs about .49 of a pound. The air is pressing on the surface of the mercury hard enough to make the mercury rise in the tube to a height of about 30 inches. Then the air must be pressing about 14.7 pounds per square inch. This great pressure of 14.7 pounds per square inch upon us amounts to a tremendous total when we consider the number of square inches on our bodies.

Blood Pressure.—Blood pressure for children and young people is about 17 pounds per square inch or about 2 pounds more than the atmospheric pressure. As people get older, the blood pressure increases somewhat.

FIG. 34.—Barometer.

Making the Barometer.—Imitate Torricelli, and fill a glass tube about 3 feet long with mercury and invert it in a small dish of mercury. If you are at sea level the mercury will drop until it stands at about 30 inches, which shows that the air pressure is great enough to keep the mercury at that height. The empty space in the tube at the top will be a vacuum.

Air Pressure Varies at different heights: It has been estimated that the atmosphere extends above the earth about two hundred miles, possibly more. At the bottom of this air ocean we humans live, ordinarily on the flat lower levels. Sometimes, after much toil, we climb the little ridges and mounds called mountains, little when compared with the depth of the atmosphere. The highest of the high moun-

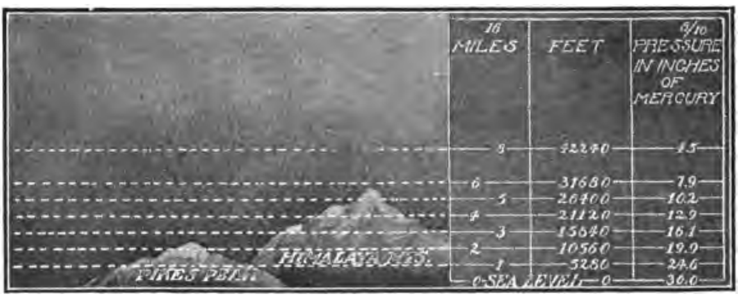


FIG. 35.—What do you think about the amount of air 25 miles above the earth? What figures on the diagram tell us that the density of the air rapidly decreases as we ascend?

tain peaks are well to the bottom of this ocean of air. This air grows rarer according to the height above the earth's surface. The greater part of the weight of the atmosphere is within three miles of the earth.

A Frenchman, Blaise Pascal, became interested in Torricelli's discovery. It occurred to him that if the atmospheric pressure supported

the mercury in the tube, as shown in Torricelli's experiment, the height of the column of mercury in the tube should increase or decrease if the pressure increased or decreased. He took up his idea with Périer, his brother-in-law, who lived near the high conical mountain of Puy-de-Dôme, and requested the latter to test his theory upon this mountain.

Fig. 36.—A mercurial barometer and an "inverted tube" one.

Périer made two tubes, filled them with mercury and observed them (duly inverted) in his garden at Clermont, the height of the mercury in the tubes being 26 French inches and 3¾ lines.

Leaving one tube behind to be observed during his absence, he took the other up the Puy-de-Dôme and, at the summit, observed that the mercury had fallen in the tube to 23 inches and 2 lines. Watching the tube while returning to the lower levels of the mountain, he found that the mercury continued to rise until by the time he reached his starting-point the mercury stood at its original level of 26 inches and 3¾ lines, at which point that in the other tube had stood during his absence.

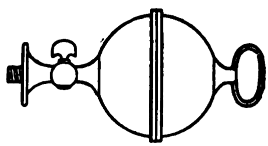


Fig. 37*a*. — Magdeburg, or von Guericke's, Hemispheres.

Satisfied with the result, Pascal proposed this process as a means of determining the height of any one place above another. Thus the "barometer" was born.

The most distinguished men of science have worked to develop from this crude but original instrument of three hundred years ago the fine instruments of the present day; yet the modern barometer is but the original "tube inverted in a cup of mercury" with many refinements.

Fig. 37*b*.—Otto von Guericke taught the people of his day something about the pressure of the atmosphere by making two hollow hemispheres which fitted nicely together and removing the air. It is said that all the horses available at the time the experiment was tried were unable to pull the hemispheres apart.

Aneroid Barometer.—A barometer is used to tell how high aeroplanes ascend, as the higher they go the lower the barometer will "drop." The type of barometer used is a non-fluid instrument called an *aneroid barometer*. It is of complicated construction.

RESULTS OF CHANGING AIR PRESSURE

Effects of Temperature on Air Pressure.—Temperature affects the reading of the barometer. The air in a schoolroom 20 feet by 30 feet would weigh 903 pounds when the temperature is 60° F., but if the temperature were increased to 80° F. the air would expand, and some of it escape. The air left would weigh 873 pounds. To be good, a barometer must be compensated for temperature, especially for measuring altitude.

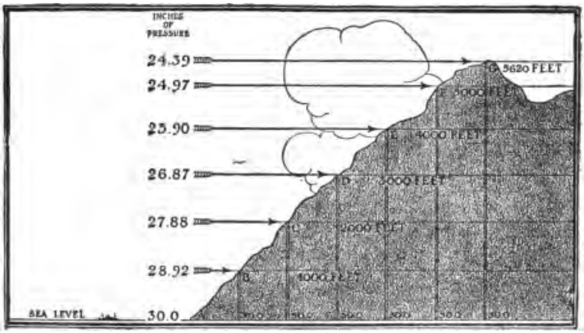


Fig. 38.—A diagram showing the relation between altitude and air pressure. Clobourg, Ill., Lowell, Neb., Spica, Kan., Kanarado, Kan., and Kanfield, Colo.

The Air Pressure Varies for Different Kinds of Weather.—When the air is heavy, the barometer reads high; and usually this occurs during fair weather. For example, 30.2 is a relatively high reading of barometer and 29 is a relatively low reading of barometer.

Sea Level.—An aneroid barometer for reading weather conditions must be corrected for altitude. Sea level means the reading of the barometer at an altitude, corrected in such a manner that it would give a reading equal to the reading of the barometer if the place of observation were at sea level instead of at an elevation. The higher we go the less the pressure of the air.

Effect of Different Pressures of the Air.—The different pressures of the atmosphere produce movements of the air. Suppose the atmosphere in our schoolroom (Effects of Temperature on Air Pressure, page 38) is heated to 80° F.

The air would now weigh 873 pounds; but suppose the air outside was 60° F. A volume of outside air equal to the volume of air in the schoolroom would weigh about 933 pounds, or 60 pounds more than the air in the schoolroom. Every cubic foot of air outside would weigh $\frac{1}{10}$ of a pound more than every cubic foot inside. This extra weight of air would press on the windows and walls, trying to get into the room. If you should hold your hand near the window you would feel the air breezing in at the places where it does not fit tightly. If you open the window you feel the air blowing in.

Ventilation.—Differences in the air pressure assist us to ventilate our houses. The heavy outside air is allowed to rush in and push out the light, warm air which has become bad. The proper ventilation of rooms is very important. The diagram on page 112 will show the effects of poor ways and good ways of ventilating schoolrooms, as well as other occupied rooms.

Drafts.—If we hold a burning joss stick near the draft of a stove, we will see the smoke going toward the opening. The air inside the stove when heated, is much lighter than the air outside There is a great pressure by the cooler air outside which crowds the hot air and smoke up the chimney. More will be said about the use of the differences in air pressure when we study methods of heating and ventilating our homes.

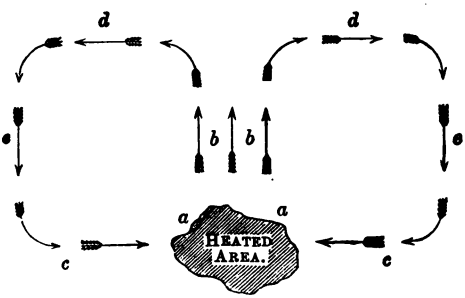


FIG. 39*a*.—Origin of winds. Why does the air at *b*, *b* rise? Why does the air at *e*, *e* fall? Why does the air at *c*, *c* move toward the heated area?

Winds.—Make a small pin-wheel and hold it over a kerosene lamp, or a Bunsen burner, high enough so it will not burn. The rising air currents will cause the pin-wheel to turn. The heated air may be observed rising if the light is between you and the window. Often, heated air may be discerned rising over radiators and stoves. If the lamp is

very large, smoke from a joss stick held on the side near the bottom will show that cold air is rushing in and pushing the heated air up. As this heated air rises it takes a counter-clockwise spiral form much like the way we see water running out of a sink at home.

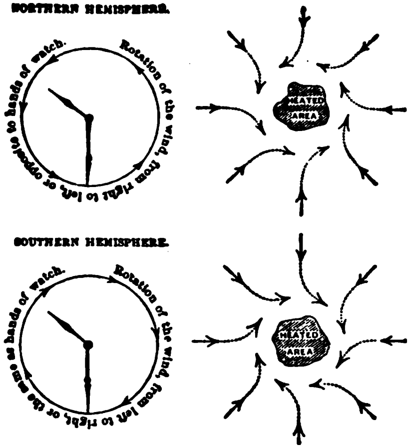


FIG. 39*b*.—Cause of the rotation of the wind.

If you could see the air as you can see water it would seem like the Whirlpool Rapids of Niagara—all swirls, pockets, vortexes and curling eddies. The inclined rock bottom of the Niagara below the falls makes the Whirlpool Rapids what they are. But the vortexes and currents of the air are due to the constant efforts of the atmosphere to find its temperature level.

Lows and Cyclones.—Suppose the barometer reads lower in Indiana than in any of the surrounding states. Naturally, air from the northern, southern, eastern and western encircling areas would rush in, pushing upward the lighter air over Indiana. Even a small difference in the reading of the barometer would mean great pressure. Every inch of the barometer dial signifies about ½ lb. per sq. in. atmospheric pressure, so that at that difference in the barometer, the readings between, say, Florida and Indiana would imply a pressure of the air toward the Indiana "low barometer" area equivalent to over 1,000,000 tons per square mile.

FIG. 40.—Photograph of a distant tornado.

These great eddies or swirls in the atmosphere are known as "cyclones" and "anticyclones." The eddies, hundreds of miles in diameter, move bodily across the country eastward at an average speed of some-

thing like 500 to 1000 miles a day. While they are near us, we generally have strong winds; as they move away, the winds subside.

Cyclonic areas are those in which the air moves around toward a region of low pressure. *Anticyclonic* areas are areas in which the air moves outward from a region of high pressure. In our latitudes cyclones and anticyclones succeed each other every two or three days.

How the Cyclones Affect the Direction of Local Winds.—If a "low barometer" area is westward from the observer the wind he will experience is an east wind; if the low area is eastward from him, the wind will be a west wind, and so on.

How "Low" Affects Weather.—While the winds are coming in from over large bodies of water, much moisture is being absorbed by the air, to be borne inland. On the Atlantic Coast, it is easy to see, the easterly winds, coming as they do from over the sea, bring rain; while westerly winds bring fair weather.

How to Tell the Velocity of the Wind.—The tables are given below to determine the velocity of the wind.

Force.	Designation.	Miles per Hour.	Average Pressure in Pounds per Square Foot.	Effect.
0	Calm	0 to 3	.01	No movement of leaves or smoke.
1	Light air	3 to 8	.25	Slight movement of leaves and smoke turned from vertical.
2	Light breeze	8 to 13	.5	Moves small branches.
3	Gentle breeze	13 to 18	1.4	Blows up dust, moves the medium-sized branches.
4	Moderate breeze	18 to 23	2.5	Moves large branches.
5	Fresh breeze	23 to 28	3	Sways trees.
6	Strong breeze	28 to 34	5	Sways trees and breaks small branches.
7	Moderate gale	34 to 40	7	Bends small trees over.
8	Fresh gale	40 to 48	10	Breaks small trees down.
9	Strong gale	48 to 56	15	Breaks off large branches.
10	Whole gale	56 to 65	19	Blows off bricks from exposed chimneys, and shingles from roofs.
11	Storm	65 to 75	26	Uproots trees, blows down frail houses.
12	Hurricane	Over 75	31	Prostrates everything.

At 100 miles per hour wind pressure would be over 50 lbs. per square foot.

1. Before a storm why does smoke from a chimney fall toward the ground?

FIG. 41.—An anemometer. What is the meaning of anemometer?

2. Why is air full of water vapor lighter than dry air?

3. How high will water rise in a pump? Why?

4. If water will rise only about 30 feet in a pump, how is it possible to get water from a well 100 feet deep?

5. Is smoke pushed or pulled up a chimney?

6. Why do balloons rise? When will a balloon stop rising?

7. Why will a fireplace or stove smoke when the fire is first started?

8. How could the smoking be prevented?

9. What is meant by a draft in a chimney?

10. Why do tall chimneys have a better draft than short chimneys?

11. What is the best way to air out a room?

WINDS AND WEATHER

Isobars and Isotherms.—The different stations send to Washington each day their reading of the barometer. Lines called *isobars* are drawn on maps through the places where the *barometric pressures* are the same. If the lines are close together there is a great difference of pressure. Such a low is accompanied by a great deal of wind. If the lines are far apart the opposite is true. Sometimes such lows die out entirely. At other times they develop into vigorous storms. These irregularities are rare, but when they do happen, they, of course, upset the weather forecast. The lows travel on the average from 500 to 1000 miles per day.

The heavy lines are called *isotherms*. They run through places of *equal temperatures*.

Floor or Wall Weather Maps.—A very helpful way to study the weather conditions is to have a map made of linoleum large enough to place on the floor. Such floor maps may be purchased for a small amount. Discs with concentric circles may be used for lows and highs. Black discs with white circles represent the highs, and

white discs with black circles the lows. If five minutes of each school period are used to arrange the discs according to the weather map, predictions may be easily made.

There should be three kinds of discs, some with the isobars close together, some far apart, and some of medium separation. There should also be discs marked

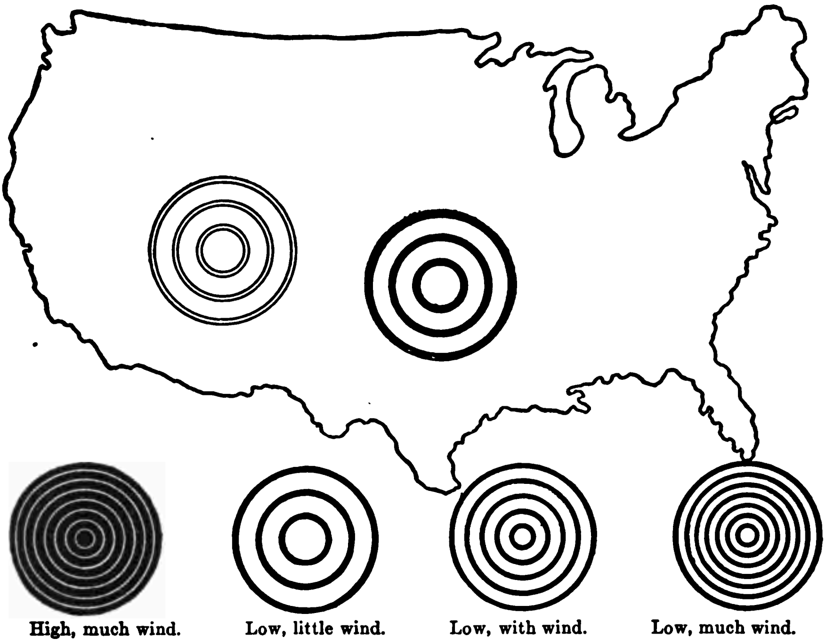


FIG. 42.—A floor map for weather prediction. The low with light lines shows where the low with the dark lines was the day before. All the highs and lows for to-day and the day before should be placed on the floor map each day according to the U. S. Weather Map. The action of highs and lows according to direction and speed may be easily studied.

"Yesterday" which should be placed on the map at the same time to show the direction and distance the high or low traveled from one day to the next.

Another method is to use the map on the wall as a bulletin board. This is not so satisfactory, as it is not placed in true directions, north and south.

Directions of Winds.—When the wind sets in from points between south and southeast, and the barometer falls steadily, a storm is approaching from the west or northwest; and its center will pass near to the

north of the observer within twenty-four hours, with winds shifting to northwest, by way of southwest and west. Place a disc on the map northwest of your State. Air is blowing in toward the center of the disc; or a low is passing over your State from the southeast toward the northwest.

When the wind sets in from between east and northeast, and the barometer falls steadily, a storm is approaching from the south or southwest, and its center will pass near to the south of the observer within twenty-four hours, with winds shifting to northwest by way of north. The rapidity of the storm's approach, and its intensity, will be indicated by the rate and the amount of the fall in the barometer.

General Indications.

Barometer Rising

1. A gradual but steady rise indicates settled fair weather.
2. A very slow rise from a low point is usually associated with high winds and dry weather.
3. A rapid rise indicates clear weather and high winds. The barometer rises for northerly wind (including from northwest, by the *north*, to eastward), for dry or less wet weather, for less wind, or more than one of these changes—except on a few occasions when rain, hail or snow comes from the northward with *strong* wind.

Barometer Falling

4. A gradual but steady fall indicates unsettled or wet weather.
5. A very slow fall from a high point is usually connected with wet and unpleasant weather, without much wind.
6. A sudden fall indicates a sudden shower, or high winds, or both.

The barometer falls for southerly wind (including from southeast by the *south* to the westward), for wet weather, for stronger wind, or for more than one of these changes—except on few occasions when *moderate* wind with rain (or snow) comes from the northward.

" Veering " wind is a wind that moves from left to right; i.e., " clockwise."

If the wind shifts the opposite way, the change is called "backing," indicating the approach of another storm.

" When the wind veers against the sun,
Trust it not, for back 't will run."

Weather Forecast.

Barometer Reading.	For Falling Barometer	For Rising Barometer
30.8–31	Continued cool, warmer and cloudy to-morrow.	Southeast rains with high winds.
30.5–30.8	Fair and warmer, followed by wind and rain.	Clear to-night, and continued cool with moderate winds.
30.2–30.5	Storm brewing in the direction of the wind.	Generally fair, probably cool to-day with variable winds.
29.9–30.2	Cloudy and warmer, followed by unsettled.	Fair, with brisk winds, which will diminish.
29.6–29.9	Unsettled, increasing winds and warmer.	Fair, with fresh winds to-night and to-morrow.
29.3–29.6	Clearing, slight squall, fair and cooler to-morrow.	High winds, with cool wave, preceded by squall.
29.0–29.3	Clearing, with high wind, accompanied by squalls and cooler.	Clearing, with high winds and cool wave.
28.7–29	Stormy.	Increasing winds followed by colder weather.
28.4–28.7	Very stormy.	

EFFECT OF TEMPERATURE ON THE WEATHER

Barometer Rising

Below 30° F. . . . . Cold wave.
Between 30° and 40° F. . . . . Freezing.
Between 40° and 50° F. . . . . Probable frost.
Between 50° and 60° F. . . . . Cooler.
Above 60° F. . . . . Warm with cool nights.

Barometer Falling

Below 30° F. . . . . Snow storm.
Between 30° and 40° F. . . . . Rain or snow.
Between 40° and 50° F. . . . . Rain storm.
Between 50° and 60° F. . . . . Heavy rains.
Above 60° F. . . . . Showers.

WINDS

Barometer Rising

S. to S.W.

Barometer 30.0 inches, or below, and rising slowly.

Clearing within a few hours, and continued fair for next few days.

S.W. to N.W. Barometer 30.10 to 30.20 inches, steady.	Fair, with slight temperature changes.
S.W. to N.W. Barometer 30.10 to 30.20 inches rising rapidly.	Fair, followed within forty-eight hours by warmer and rain.
Going to W. Barometer 29.80 inches, or below, and rising rapidly.	Clearing and colder.
Between N. and E. Barometer rising.	Weather turning cooler.
Between S.W. and S. Barometer rising.	Weather probably warmer to-morrow, but cloudy.

WINDS

Barometer Falling

S. to E. Barometer 29.8 inches and below and falling rapidly.	Severe storm of rain (in summer) or snow (in winter) imminent, clearing and colder in 24 hours.
S. to S.E. Barometer 30.1 to 30.2 inches, falling rapidly.	Rain in 18 to 24 hours.
S. to S.E. Barometer 30.1 to 30.2 inches, falling slowly.	Rain in about 24 hours.
E. to N.E. Barometer 30.10 and above and falling slowly (winter).	Rain or snow within 24 hours.
E. to N.E. Barometer 30.10 and above and falling slowly (summer).	With light winds; rain may not fall for several days.
E. to N.E. Barometer 30.10 inches and above and falling rapidly (summer).	Rain probable within 12 to 24 hours.
E. to N.E. Barometer 30.10 and above and falling rapidly (winter).	Rain or snow, with increasing wind, especially if wind is from N.E.
S.W. to N.W. Barometer above 30.2 inches and falling slowly.	Slowly rising temperature and fair for 48 hours.
S.W. to N.W. Barometer 30.1 to 30.2 inches and falling rapidly.	Warmer, with rain in from 18 to 24 hours.

S.W. to N.W. Barometer 30.1 to 30.2 inches and falling slowly.	Warmer, with rain in from 24 to 36 hours.
S.E. to N.E. 30 and below and falling rapidly.	Rain, with high winds, followed in 24 hours by clearing and cooler.
S.E. to N.E. 30 and below and falling slowly.	Rain for one or two days.
E. to N. Barometer 29.8 or below, falling rapidly.	Severe N.E. gales and heavy rains or snow, followed in winter by cold wave.
S.E. to S.W. With barometer falling.	Storm coming from W. or N.W. followed by cooler and W. to N. W. winds.
N. and E. With barometer falling.	Storm coming from S. to S.W., followed by cooler and N. to N.W. winds.

World Winds.—The air at the equator becomes heated and rises, while cold air from the north blows toward the equator to take the place of the warm air rising there. The air moving from the north will become heated and part of it will begin to rise near latitude 30°, joining the warm air traveling from the equator on its way to the north. A part of the air from the equator will become cold, and flow downward, joining the cold air going toward the equator at latitude 30°.

These places on the earth's surface are called "horse latitudes."

Here air has an upward and downward movement, and there is no steady horizontal wind. The term "horse latitude" originated with sailors in the days of sailing vessels which carried horses from New England to the West Indies. Vessels were delayed by calms for a long time, fresh water would give out and the sailors would be forced to throw the horses overboard.

Belts of Calms.—At the equator the warmed air is continually rising and cold air falling. There is little wind blowing horizontally. Such a condition causes a region of calms about 100 miles on each side of the equator. Why was this so troublesome to sailors years ago, and of little account to sea captains to-day?

Trade Winds.—The air flowing toward the equator causes very steady winds, called *trade winds*. Winds blowing away from the equator are called *anti-trade winds*. As air approaches the equator, it

becomes warmer and, of course, receives and holds more moisture. The trade wind area is known as the clear-weather belt.

The Prevailing Westerlies.—Between the horse latitudes and the poles the winds have a westerly trend because of the rotation of the earth. Pour a small amount of water at the north end of a rotating globe. The rotation of the globe causes the water to trend in a westerly direction above the equator, and easterly below the equator.

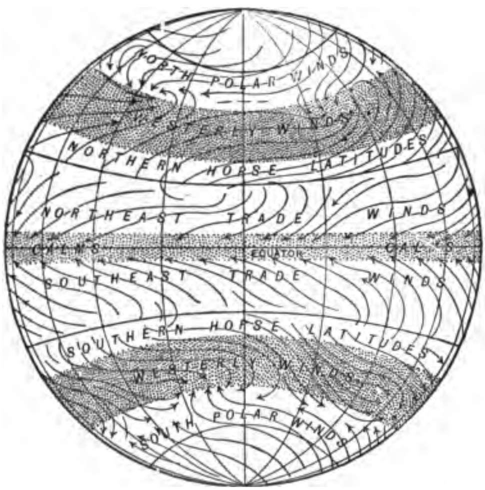


FIG. 43.—The wind belts on the rotating earth.

Sea Breezes and Land Breezes.—During the day the earth becomes warmer than the water. The air over the earth rises, while the cooler air from over the ocean moves toward the land, causing sea breezes. At night the opposite condition is true, as the land cools off much faster than the water.

Monsoons. — Monsoons are winds which blow from the Indian Ocean to the heated lands toward the Himalaya mountains. Such winds blow from May to October. During the remaining part of the year the land is cooler than the water and the wind blows toward the ocean.

Tornadoes.—Tornadoes are immense whirlwinds which are caused by overheated conditions. They are preceded by the formation of a whirling inverted-cone cloud mass. The funnel shape is due to the spiral character of the rotary motion.

The influence of tornadoes is felt only over limited areas, but the extremely low barometric pressures that attend them, and the high wind velocity, sometimes exceeding 100 miles an hour, make them very destructive.

Why a Kite Remains Up in the Air.—A kite remaining high in the air is an example of the pressure of the atmosphere in motion. In

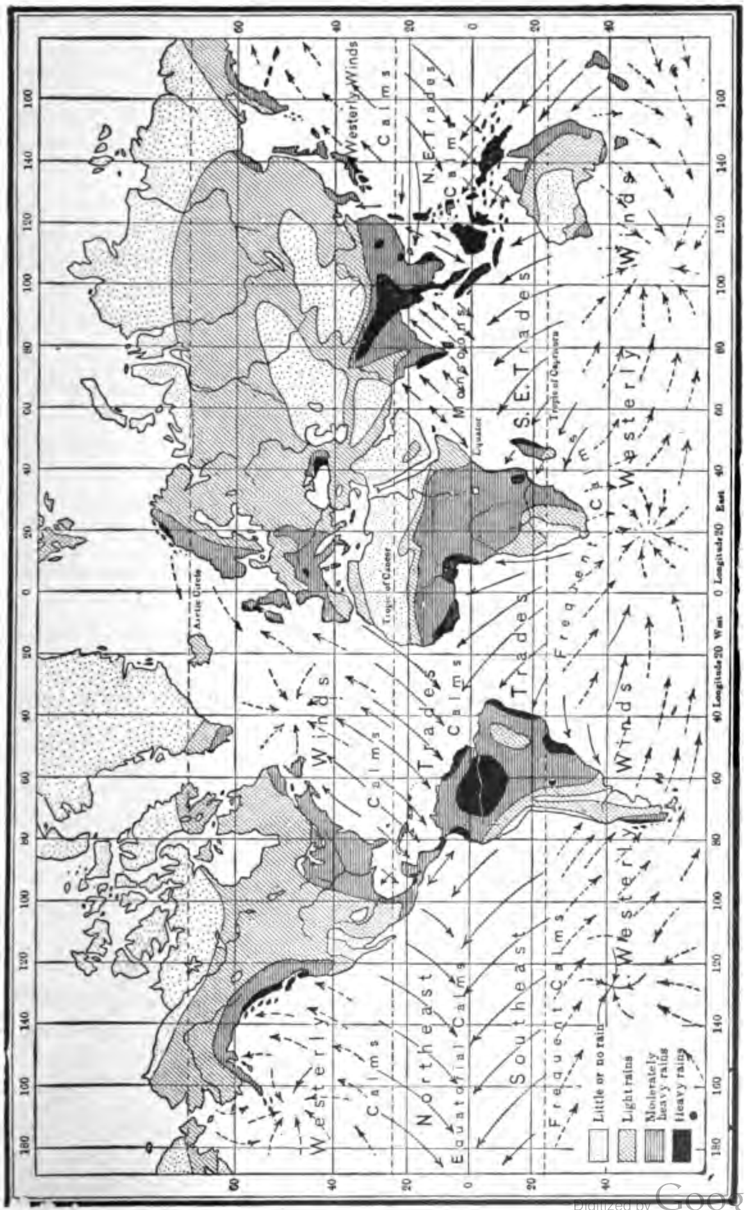


FIG. 44.—Winds of the World

flying a kite a boy will run "against the wind" in order to make enough pressure to force the kite upward, since near the earth the trees, buildings and hills interfere with the constant pressure of whatever horizontal breeze there may be at the time. After the kite has risen to a height, where the breeze is steady, above the objects which interfere with the wind, it will remain in about the same position.

Experiment for Studying the Pressure of the Upper Current.—Some idea of the pressure of the moving air current may be obtained by flying a kite which has a known number of square feet of surface. Attach a spring balance to the end of the string. Make a series of readings for 10 or 15 minutes, noting whether the pressure of this current remains constant.

What is the pressure per square foot on the surface of the kite?

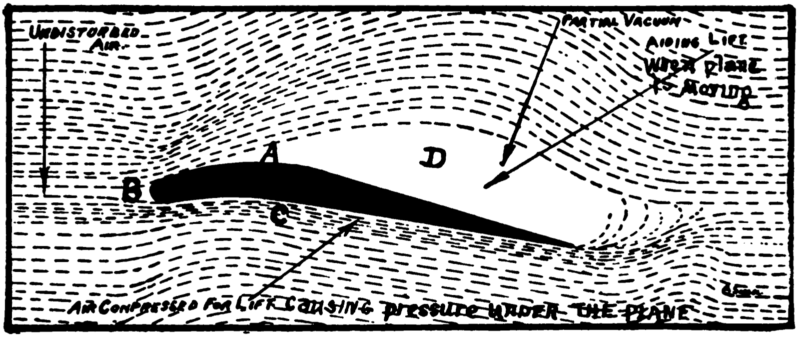
Questions

1. Fill a sink or basin with water. Place a piece of any material which will float, on the water. Pull the stopper.

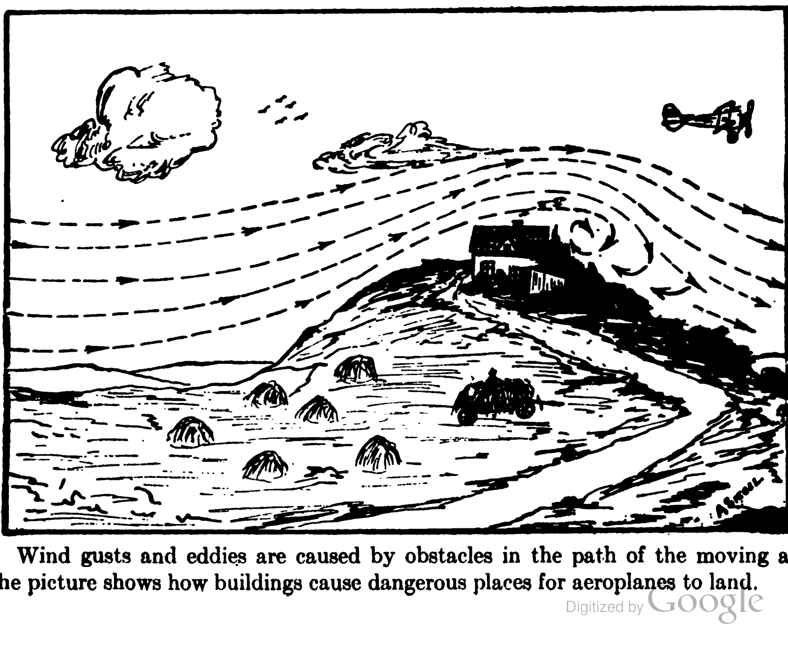
Which way does the water run out of the sink or basin, clockwise or counter-clockwise? Does it run in the same direction every time you try it? Why does the water take a spiral motion? Which way would the water run out in the southern hemisphere?

2. If a low is in Iowa, which way will the wind blow in North Dakota? Indiana? Kansas? Wisconsin?
3. Why is there always a breeze near a large fire?
4. What winds bring rain to your section of the country?
5. Why do people at the center of a low feel no wind blowing?
6. Why does the barometer drop as a low approaches?
7. Why are cyclones called lows?
8. Why are anticyclones called highs?
9. Explain how a kite is kept in the air.

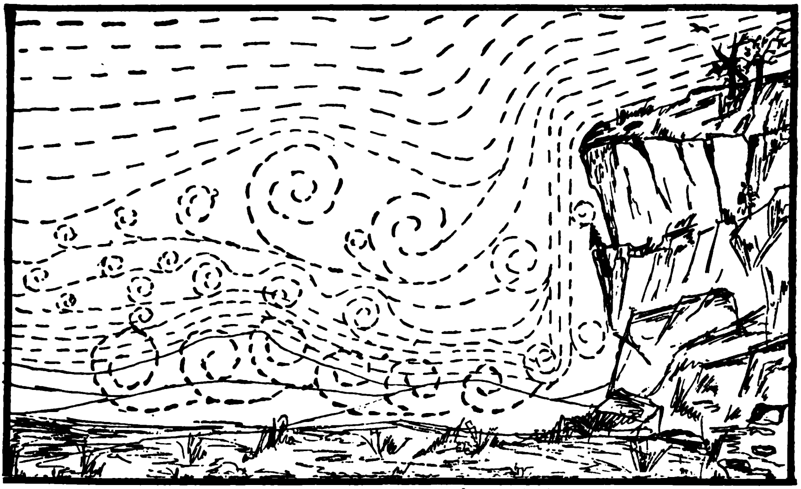
AIR PRESSURE AND THE AEROPLANE



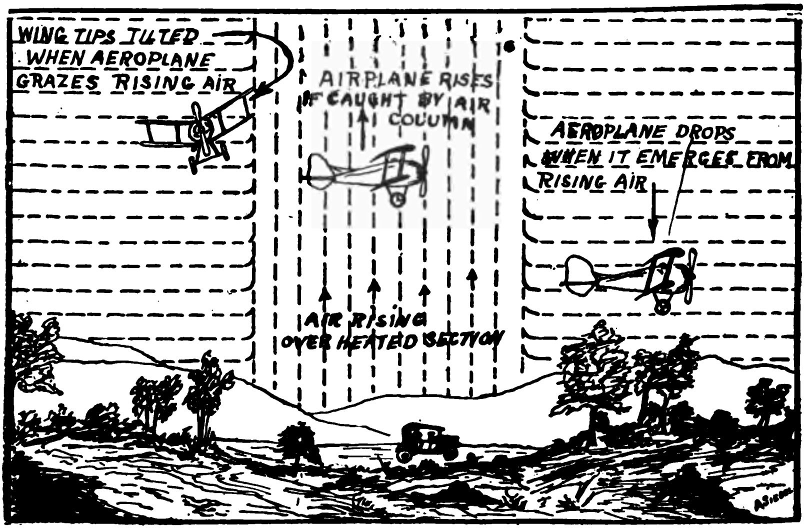
Atmosphere has weight and exerts pressure. *A* represents a plane or wing passing through the air. At *B* the air is being separated by the forward motion of the plane. At *C* the air is compressed, giving a lifting force to the plane, while at *D* the air is much rarefied, a partial vacuum being formed which overcomes the air pressure on the top of the wing or plane. The pressure of the air against the main wing surfaces enables the aeroplane to fly, the pressure supplied being according to the speed of the propeller.



Wind gusts and eddies are caused by obstacles in the path of the moving air. The picture shows how buildings cause dangerous places for aeroplanes to land.

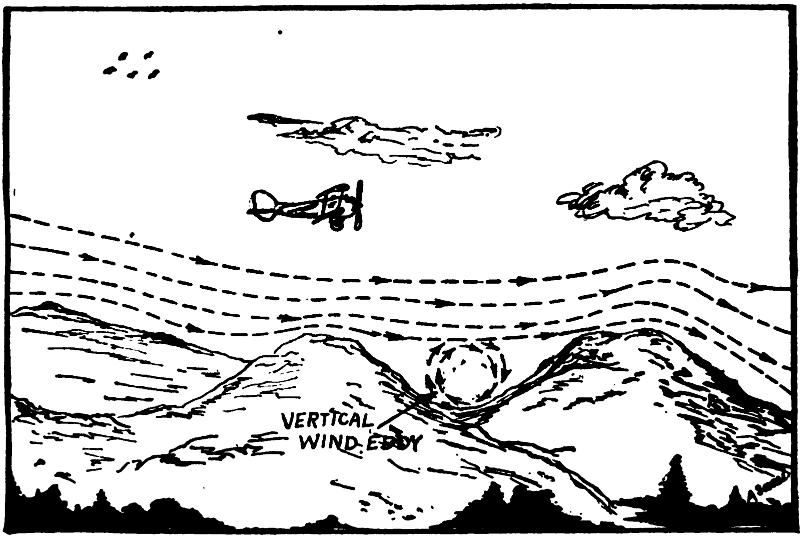


An Aerial Cascade is caused by the rebounding of air at the bottom of a steep fall Aviators must remain above the eddies to avoid grave peril.

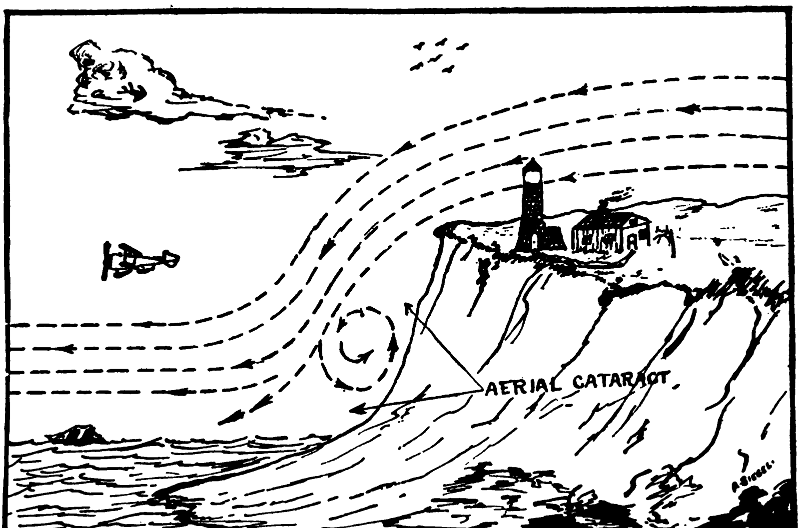


Aerial fountains are caused by rising currents of warm air during warm weather. An aeroplane entering an aerial fountain tends to rise because of the upward motion of the air. As a rule aerial fountains are not dangerous.

Aerial torrents act in the opposite manner. The cold air rushes downward.



Vertical wind eddies form below the crest of hills. Currents dangerous.



Aerial cataracts are encountered near cliffs or steep slopes. In thunderstorms cataracts are dangerous; Landings made in them are usually disastrous.

OBSERVATIONS AND PREDICTIONS OF THE WEATHER

Weather Signals.—The following weather signals are used by the United States Weather Bureau, Department of Agriculture.

A white flag, 72 inches by 72 inches, alone, indicates fair weather.

A blue flag, 72 inches by 72 inches, alone, indicates rain or snow.

A blue and white flag (white part 72 inches by 36 inches, blue part 72 inches by 36 inches) indicates local rain or snow.

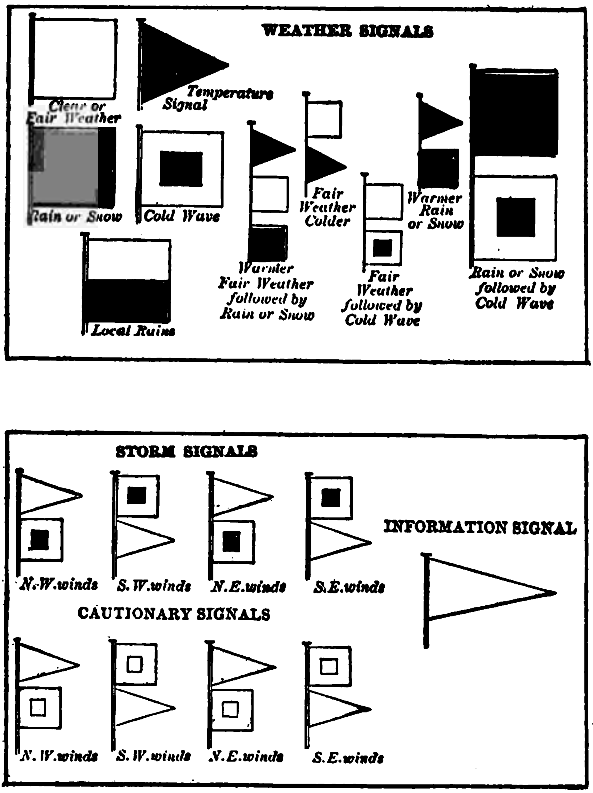


FIG. 45.

A white flag with a black center (white part 72 inches by 72 inches, black part in center 24 inches by 24 inches) indicates cold wave.

A black triangular flag, 45 inches at the base and 72 inches long, is used to denote temperature.

A white flag, with a black triangular flag above it, indicates fair and warmer.

A white flag, with a black triangular flag below it, indicates fair and colder.

A blue flag, with a black triangular flag above it, indicates rain or snow, and warmer.

A blue flag, with a black triangular flag below it, indicates rain or snow, and colder.

A blue and white flag, with a triangular black flag above it, indicates local rain or snow, and warmer.

A blue and white flag, with a triangular black flag below it, indicates local rain or snow, and colder.

The following signal flags are used for small craft, storm and hurricane warnings:

Small Craft Warning.—A red pennant indicates that moderately strong winds are expected.

Storm Warning.—A red flag with a black center indicates that a storm of marked violence is expected.

The pennants displayed with the flags indicate the direction of the wind: white, westerly (from southwest to north); red, easterly (from northeast to south). The pennant above the flag indicates that the wind is expected to blow from the northerly quadrants; below, from the southerly quadrants.

By night, a red light indicates easterly winds, and a white light below a red light, westerly winds.

Hurricane Warning.—Two red flags with black centers, displayed one above the other, indicate the expected approach of a tropical hurricane, or one of those extremely severe and dangerous storms which occasionally move across the lakes and northern Atlantic coast.

No night small craft or hurricane warnings are displayed.

Recording the Amount of Cloudiness.—If the sky is $\frac{3}{10}$ or less covered with clouds, the day is called clear; $\frac{4}{10}$ to $\frac{7}{10}$, partly clouded; $\frac{8}{10}$ and over, cloudy.

PREDICTION OF WEATHER BY SPECIAL OBSERVATIONS

The following material is often used by people roughly to forecast weather. This should be studied to determine whether any of the sayings are fallacies.

To Predict Weather by Casual Signs.

"Halo" around the moon.

The smoke falling toward the ground.

Indication of storm, as the barometer is reading low, and the atmosphere full of water vapor is lighter than the smoke. Dry air is heavier than air full of water vapor.

To Predict Weather by the Clouds.

Soft-looking or delicate clouds foretell fine weather.

Small black clouds foretell rain.

To Predict Weather by the Sky.

A bright blue sky indicates fair weather.

Yellow sky at sunset, wind.

Pale yellow, rain.

Dark, gloomy, blue sky, light wind.

Dark, oily looking clouds, wind.

Rosy sky at sunset, fine weather.

Sickly looking green hue, wind and rain.

Streaks in the sky, often miscalled "the sun drawing water," foretell rain; the sun is shining through an excess of moisture in the sky, between the clouds.

Rainbow in the afternoon, fair weather.

A dark red sky, rain.

A red sky in the morning, wind and rain.

Gray sky in the morning, fair weather.

Remarkable clearness of the atmosphere near the horizon, distant objects, hills, islands raised or unusually visible; and what is called a good hearing day, foretell rain and wind. This condition is called a "land loom" by fishermen, who usually prepare at once for a storm.

After fine weather, the first signs in the sky of a coming change are usually light streaks, curls, wisps, or mottled patches of distant white clouds which increase, and are followed by an overcasting of murky vapor that grows into cloudiness. The appearance indicates wind and rain, and may be observed in the atmosphere sometimes two or three days before a storm.

If the sun before setting appears diffused and of a brilliant white, it foretells storm.

If it sets in a sky slightly purple, the atmosphere near the zenith being of a a bright blue, we may look for fine weather.

Above the rest, the sun who never lies,
Foretells the change of weather in the skies;
For if he rise, unwilling, to his race,
Clouds on his brow and spots upon his face,
Or if through mist he shoots his sullen beams,
Frugal of light, in loose and straggling streams,
Suspect a drizzling day and southern rain,
Fatal to fruits, and flocks and promised grain.

Dew and fog indicate fine weather.

"Evening red aud morning gray; two sure signs of one fine day."

Weather Lore

"When the wind veers against the sun,
Trust it not, for back 't will run."

"When the wind is in the east,
'Tis good for neither man nor beast."

"If hoar-frost comes on mornings twain,
The third day surely will have rain."

"If clouds look as if scratched by a hen,
Get ready to reef your topsails then."

"Mackerel sky, mackerel sky,
Not long wet, nor yet long dry."

"If the sun goes pale to bed,
'T will rain to-morrow it is said."

"Long foretold, long last,
Short notice, soon past."

"Evening red and morning gray,
Help the traveler on his way."

"When the glass falls low, prepare for a blow,
When it rises high, let all your kites fly."

"An evening gray and morning red,
Will send the shepherd wet to bed."

"Mackerel sky and mare's tails,
Make lofty ships carry low sails."

Other Signs.—Spiders are sensitive to atmospheric changes. Every twenty-four hours the spider makes some alteration in its web to suit the weather. When a high wind or heavy rain threatens, the spider may be seen taking in sail, shortening the rope filaments that sustain the web structure. If the storm is to be unusually severe or of long duration, the ropes are strengthened, as well as shortened.

On the contrary, when you see the spider lengthening the slender filaments, it is certain that calm, fine weather has set in, the duration of which may be measured by their elongation. When the spider sits quiet and dull in the middle of its web, rain is not far off. If it be active, however, and continues so during a shower, the rain will be of brief duration, and sunshine will follow. When you see the spiders coming out of the walls more freely than usual, you may be sure that rain is near.

Leech Barometer.—If there is an aquarium in the schoolroom the following material will be found an interesting addition to this work.

Leeches are exceedingly sensitive to weather changes. Fill a jar with pure water and cover the opening with muslin, after placing a leech inside. During fine weather the leech lies motionless at the bottom of the jar. When rain is coming, it climbs to the upper part and seems generally unsettled. At the coming of wind or thunder, it becomes extraordinarily active, moving rapidly about and scarcely staying in one place for ten seconds. *Change the water at least once a week.*

Frog Barometer.—The same kind of jar that was used for the leech may be used for the frog barometer. In this case a small wooden ladder should be used, and the water in the jar should not come beyond the third step. When the weather is likely to be fine and dry, the frog remains below the water most of the time. At the approach of rain it climbs up the ladder, and sits entirely out of the water; as the weather becomes clear, it returns to the water. *Change the water at least once a week.*

Questions

1. What are some of the signs of approaching rain?
2. How are people who are troubled with rheumatism or neuralgia affected by the weather?
3. What weather flags would you use to-day?

Questions for Investigation

1. How are you physically conscious of an approaching storm?
   What conditions of the air make you feel the approaching storm?
   How long before the arrival of a storm are you able to predict its approach?
2. From what directions does the wind usually blow before a storm? From what directions does the wind usually blow after a storm?
3. Compare the velocity of the wind just before, during and after a storm.
4. Compare the temperature before, after and during a storm.
5. Just before a storm, is the sky more or less cloudy?
6. How does the sky look after a storm?

BOILING POINT

Atmospheric Pressure and Rate of Evaporation.—Water evaporates more rapidly in high places, where the atmospheric pressure is low, than in valleys.

Altitude and the Boiling Point.—At sea level if we fill a flask half full of water and apply heat, the water will not begin to boil until it has reached a temperature of about 212° F.; but in Denver, Colo., the water will boil at about 203° F. because Denver is over 5000 feet above sea level, and the air pressure is not so great. An ascent of about 596 feet discloses a difference of 1° F.

Water while boiling is violently agitated by steam bubbles which are formed at the bottom of the flask, nearest the flame. The steam bubbles rise and burst, sending off steam with a pressure greater than that of the air. In other words, the pressure of steam at sea level must be over 14.7 pounds per square inch, and in Denver 11.4 lbs. per sq. in.

Boiling point varies about .88 of a degree Fahrenheit for a variation in the barometer of half an inch. Water boils in a practical vacuum, or when the mercury has fallen to .24 of an inch (0.1176 pound pressure),

FIG. 46.—How hot would boiling water be on Pike's Peak? In Denver, Colo.? In Spica, Kan.? In Kanfield, Colo.? In New York?—the barometer reading 30 inches at sea level. How is it possible for an aeroaunt to tell with a barometer how high he is above the ground? Why could Mark Twain tell how high up in the Alps he was by "boiling his thermometer"?

at about 40° F., which is the lowest temperature at which water will boil under those conditions.

At the top of Mt. Blanc in Switzerland, which is three miles high, water boils at 185° F. A traveler could not "boil" eggs (hard) at the top of this mountain, as the white of an egg will not harden unless the temperature is far in excess of 185° F.

Boiling Point of Different Substances.—Not all substances boil at the same temperature. The following table gives a few of the common substances which have different boiling points.

	Fahrenheit.
Water	212°
Kerosene	365–392
Gasoline	112–140
Alcohol	172°
Sulphur	831
Mercury	674
Ether	98

Questions

1. Why does water boil more easily on some days than on others?
2. Why do some say "it is going to rain," when the "kettle boils easy"?
3. How could one tell the height of a place by the temperature there of boiling water?
4. Why will a heavy cover over a dish cause vegetables to cook more quickly?
5. Why is it impossible to boil eggs (hard) at high altitudes unless the cover of the kettle is weighted down?

Fig. 47.

6. If the atmosphere were all removed from the earth, would the ocean boil? Why?
7. Would ice-water boil in a vacuum?
8. What causes the water to rise in a coffee percolator?
9. What part of each section of this Chapter did you like best?
10. What part of the Chapter do you consider of greatest importance? Why?

CHAPTER IV

TRANSMISSION OF HEAT

RADIATION

The Sun as a Source of Heat.—Our most important source of heat is the sun. The sun is supposed to have a temperature of about 10,800° F. Scientists have estimated that a solid column of ice 2½ miles in diameter reaching from the earth to the sun (about 92 million miles), would melt in a single second if the entire heat of the sun were concentrated on the ice. If the sun were composed of burning coal it would burn out in less than five thousand years. Since the earth is millions of years old, the sun cannot be burning in that sense. The scientist, Helmholtz, first satisfactorily explained why the sun continues to give off heat. He advanced the idea that the enormous weight of the sun causes tremendous internal contraction which produces heat. Newcomb, another scientist, has estimated that in about 7 million years the sun will be one-half its present size.

How the Heat of the Sun Reaches the Earth.—Heat, along with light, comes to us from the sun, in what we call rays. The process is called **radiation.**

As to the process, we know regarding the earth's atmosphere, the higher the altitude the colder the air. About 10 miles above the earth the temperature of the atmosphere is about 90° below zero, Fahrenheit, while the space beyond our atmosphere is estimated to have little, if any heat, the temperature being about 459° F. below zero. This would seem to tell that the sun does not send us heat as such. Across this enormous cold space light and heat waves travel without warming any part of space, because, as is believed, this "vacuum" beyond our atmosphere is a transparent, intangible, and invisble medium called **ether.** These heat and light waves are spoken of as **radiant energy.**

If you put your hand on a window-pane through which the "sun is shining," the window will feel cold, the window-sill warm. Air, glass, and many liquids are transparent; that is, the light passes through them freely. The radiant energy, which is coming from the sun and traveling at a rate of about 186,377 miles per second, passes through these and other transparent objects, as well as through the ether, without losing heat. When the radiant energy encounters the window sill, which is opaque, heat results.

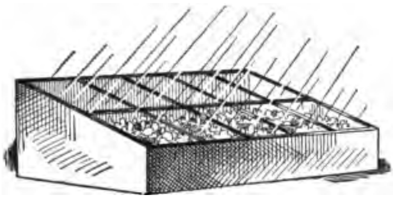


FIG. 48.

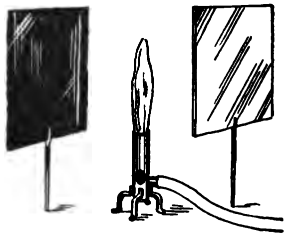


FIG. 49.

The glass of hotbeds and hothouses permits the radiant energy to pass through and strike the soil. The encounter develops heat, which cannot pass out through the glass.

Dull and Shiny Objects.—When radiant energy reaches any object it may be passed through the substance, or be absorbed by the substance, or else be reflected by its surface.

Stand two pieces of dark metal (one shiny and the other dull) upright about a foot apart. Place between them a bright light.

In a short time the dull metal will be warmer than the shiny metal. The dull metal absorbed the radiant energy and was warmed, while the shiny metal reflected the heat and light.

It is because white clothing reflects the radiant energy in light that it is cooler for use in summer than dark clothing.

Why Water does not Heat as Quickly as the Soil.—For one thing, clean water is transparent. Besides, the bright surface of still water reflects sun rays that strike it slantingly. But the soil is opaque and its surfaces dull.

One cause of sunburn is the glare from reflected sunlight.

Why Soil Cools off Faster than Water.—Substances which absorb radiant energy readily also radiate heat readily.

Fill two metal cans (one shiny and the other dull) with water at the same temperature. Cover each can with a piece of wood. Note the temperature of the water every few minutes. State your conclusion.

A shiny metal cup if covered with black soot will radiate heat twenty times faster than the same cup when clean and bright, and fifty times faster than a burnished silver cup. The rocks and soil of the earth radiate heat much more quickly than bodies of water. (The specific heat of water is greater than that of soil.)

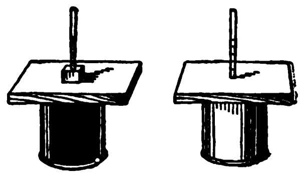


FIG. 50.

Radiation and the Household.—Stoves, steam radiators, hot air radiators, and other devices for yielding warmth, should be dark; cooking utensils, hot-air flues, and pipes for conveying as distinguished from yielding warmth should be light colored.

A bright nickel or aluminum kettle will cool much more slowly than a black kettle. On a coal or wood stove a kettle is heated largely by heat radiated from the stove; over a gas flame, or the blue flame of an oil burner, the condition of the bottom of the kettle will not make so much difference, since here most of the heat is received by direct contact with the hot gases. The best kettle for general use is one with the bottom black and the remainder polished, but for use on a blue-flame it matters little whether or not the bottom is black.

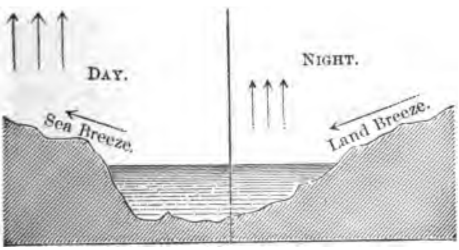


FIG. 51.—Why do we have a sea breeze during the day and a land breeze at night?

Moisture and Dust in the Air, and Radiation.—During the passage of radiant energy through the air, some of it is absorbed by the dust particles and moisture present. The amount of heat thus obtained is small, and especially so on high mountains where there is little dust and moisture in the air. The important thing is the interference with radiation by moisture and dust during the night. More heat is retained

near the earth on hazy and muggy days than during clear days and nights. On high mountains the ground becomes heated very quickly during the day, but at night the heat radiates just as quickly because of the relative clearness of the atmosphere.

Fig. 52.

Radiometer.—Darken the room. Place a radiometer on the table near a bright flame; the radiometer vanes will be seen to move very rapidly. If the light is a Bunsen burner, allow air enough to enter to make the flame blue; the vanes will go around more slowly.

The radiant energy from the bright flame passes directly through the glass, and is absorbed very quickly by the black vanes, but is reflected by the bright vanes. Much of the air has been exhausted from the bulb of the radiometer. The tiny particles or molecules of air remaining strike the blackened surface and rebound with greater velocity than from the other side, thus exerting great pressure.

The Seasons and the Slant of the Sun's Rays.—Let AB (Fig. 54) represent a section of the earth during the summer time, and CD a section during the winter time. Compare the areas marked by AB and CD, and state your conclusion.

Questions

1. Tell one reason for having thermos bottles shiny.
2. Why should radiators be dark and rough?
3. Why is white outer clothing preferable in hot weather?
4. Why will snow melt faster under black cloth than under white?
5. Why wear white in summer, and black in winter?
6. Why does dirt-covered snow melt faster than clean new snow?
7. Why doesn't the earth get heated just as much by radiation on a cloudy day?
8. Why is a body of water warmer in the evening than the adjacent land?
9. When will you get the greater sunburn—when the sea is rough, or smooth? Why?

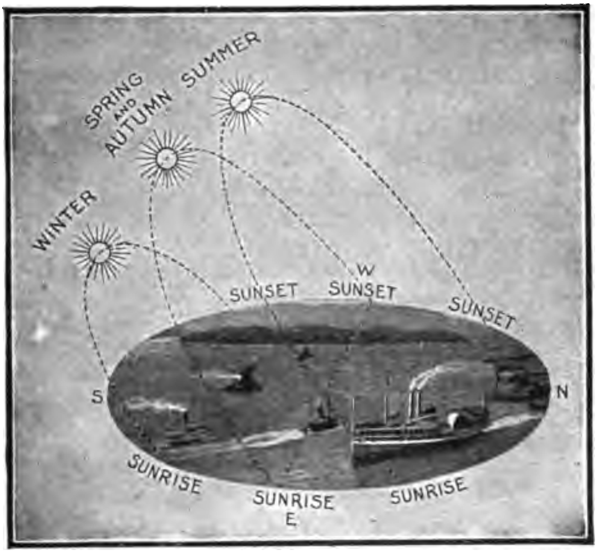


FIG. 53.—The daily course of the sun at the time of the solstices and the equinoxes.

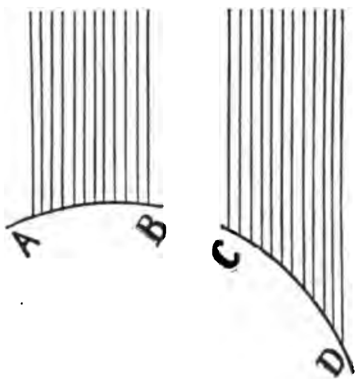


FIG. 54.—The rays *A B* strike the earth vertically, the rays *C D* strike in a slanting direction. As *D C* is longer than *A B*, the same number of rays are spread over a greater surface. State the result.

10. Why will frost appear more quickly on a clear night?

11. Why will dark soils absorb heat more rapidly than light-colored soils?

12. Why will the bare earth become heated more quickly than earth covered with vegetation?

13. How does the glass in a hothouse act as a trap to catch heat?

14. Does the heat of the sun come through the window?

15. Why are the tops of mountains so cold although nearer the sun than the valleys?

16. Why will a slight covering over plants prevent frost?

17. Why is there no frost on a cloudy night?

18. Why may flowers be raised under glass out-of-doors during the winter?

19. Why does the snow melt at the foot of a tree more quickly than in the open field?

CONDUCTION

Conduction and Convection.—There are two other ways by which heat is transmitted: *conduction,* which is to be studied in this section, and *convection,* which is to be studied in the next section.

To get a suggestion of the difference between the two methods, pass a book from one student to another along the class. The book is passed or conducted from pupil to pupil. The heat is given from one particle or molecule to another of an iron bar, one end of which is in a flame, and the other end in your hand. In this way the heat is conducted from particle to particle to your hand. The heat has traveled by **conduction.**

If one of the pupils conveys the book from one end of the class to the other, the book may be said to travel from one place to another by **convection.** Most solids transmit heat by conduction; liquids and gases by convection. For the transmission of heat by convection we use chiefly the air and water. A furnace heats the air or water which in turn carries heat as it travels throughout the building.

Substances at the Same Temperature Feel Different.—The better heat conductors take heat from the hand more rapidly than do poor conductors. In the same room, at the same temperature throughout, the bare floor will feel colder than a rug. This is because the floor takes the heat away from the bare foot or hand more rapidly than the rug.

Place a thermometer on several objects in the room which seem of different temperatures. The thermometer will register the same temperature for all.

With the hand, test as many substances in the room as possible. Tell whether they are poor, medium, or good conductors.

Different Substances Conduct Heat at Different Rates.—If several pieces of wire of different metals are covered with heat-indicating paint and arranged so that one end of each piece is over the mouth of a flask from which steam is coming and the other ends are rested on blocks of wood, the metal will conduct heat at different rates. Compare with the Table on the next page.

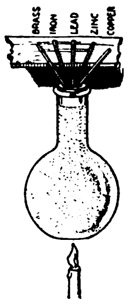


FIG. 55.

From the table on the next page it will be seen that silver is the best conductor of heat, and air one of the poorest.

Try several teakettles, placing the same amount of water in each and noting the time required to bring the water to boiling point. If the kettles do not have bottoms of the same size determine whether this has any effect on the time required to heat the water, and the consequent waste or saving of gas. Try to find other important factors besides the conductivity of the metals. Measure the amount of gas consumed, and determine the amount saved if kettles of the proper kind are used.

Poor Conductors.—Water is a poor conductor of heat, as may be shown by nearly filling a test tube with water, and, with a piece of wire, fastening some ice at the bottom of the water in the tube. Heat the test tube near the top. Soon the water in the top will boil, while ice remains in the bottom of the tube.

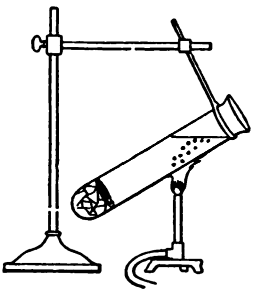


FIG. 56.

Air is another poor conductor, especially dry, dead air. By dead air we mean air not in motion. Damp air does not conduct heat very rapidly unless in motion. Often a person may remain in damp, still air without any great discomfort, after the moisture in contact with the body has been heated.

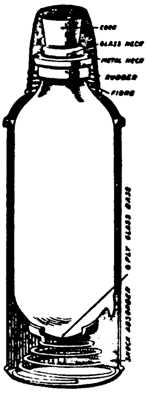


FIG. 57.

Water under a bridge will not freeze for some time after the water in the open has frozen. Shawls with many openings filled with dead air are very warm. Birds

often ruffle up their feathers on a cold day to get plenty of dead air among the spaces between the feathers. To prevent the air from circulating, charcoal, sawdust, and other porous substances are often loosely packed into spaces between walls. Leather, paper, fur, felt, woolen cloth, animal wool and many other solids are poor conductors.

TABLE

Material.	Thermal Conductivity.	Transmission in Btu. per Hr., per Sq. Ft. per in. Thickness for Each Degree F. Difference in Temperature.
1. Silver	100	2900.0
2. Copper	90	2600.0
3. Aluminum	50	1950.0
4. Brass	27	
5. Zinc	26	
6. Tin	14.7	
7. Iron	14	460.0
8. German silver	8.4	
9. Mercury silver	1.7	
10. Rock	.25–.9	0.7 to 26.0
11. Granite	.53	
12. Limestone	.52	
13. Ice	.5	
14. Porcelain	.25	7.2
15. Brick	.2–.5	6.0 to 15.0
16. Glass (ordinary)	.16	4.6
17. Water	.14	4.0
18. Plaster (ordinary)	.1–.15	2.9 to 4.3
19. Wood (hard)	.06	1.7
20. Asbestos paper	.045	1.3
Asbestos felt	.025	.7
21. Sawdust	.018	.52
22. Wood (very soft)	.015	.43
23. Paper	.013	.38
24. Cork board	.012	.34
25. Wool	.010	.29
26. Hair felt	.010	.24
27. Cotton wool	.009	.26
28. Feathers	.0057	.16
29. Air	.005	
30. Silk	.000095	
31. Snow	.00051	
32. Leather	.00037	

THERMOS BOTTLE

Why is a cork stopper used?

Why is the bottle placed on a spring (two reasons)?

Why is a space left between the outer case and the bottle?

Why is the bottle made in two sections with a vacuum between the inner and outer bottle?

What practical advantage has the shiny exterior?

Questions

1. Why are flatiron handles made of wood?
2. Why is ice stored in sawdust or straw?
3. Why do late spring snows melt from stone walks more quickly than from board walks?
4. How does clothing keep us warm?
5. Why cover plants with paper on frosty nights?
6. Why do woodsmen often wear paper vests?
7. Which would be best for a stove (for warmth)—iron, brick, or soapstone? Why?
8. Why do stove lifters have coiled-wire handles?
9. Why are dead air spaces left between the walls of a building?
10. Why do Eskimos wear one skin with the fur next to the body, and the other with the fur outside?
11. Why do birds ruffle up their feathers on a cold day?
12. Why are loosely woven stuffs warmer than tightly woven?
13. Why are shawls, sweaters, etc., said to be very warm?
14. Why does food continue to cook, placed in a fireless cooker?
15. Why make of wood the outside pail of an ice cream freezer?
16. Why does plenty of snow keep the grass roots from freezing?
17. Why is linoleum colder to the bare feet than woolen carpet?
18. Why is it possible to set paper afire with a burning glass?
19. Why do farmers prefer a winter with abundant snowfall?
20. Why do rubbers "feel so warm" if worn in the house?
21. Why use a woolen blanket to cover the ice in summer and to cover oneself in winter?
22. Why will the hand on a frosty morning freeze to a metallic surface more quickly than to a brick one?
23. In taking bread from the oven, why will the hot pan burn your

hand wherever it touches you, while the bread and the air of the oven do not, although of the same temperature?

24. Why may a glass rod be melted in a flame and held in the hand with comfort a few inches from the melting place?

25. Why are hob-nail shoes very cold in winter?

26. Why will mist clear from lenses surrounded with gold rims more quickly than from rimless glasses?

CONVECTION

Conduction, Convection, and Clothing.—Air is a poor *conductor* of heat, and if it cannot circulate so as to carry heat by *convection*, is one of the best of heat insulators. Cotton, wool, feathers, cork, etc., are good insulators because of the large amount of air in the spaces between the fibers or the cavities. Clothing keeps in the heat of the body chiefly because it contains air in the meshes and between the layers of the cloth. When in windy weather the enclosed warm air gets displaced by cold air the clothing no longer "feels so warm." If clothing is closely fitting

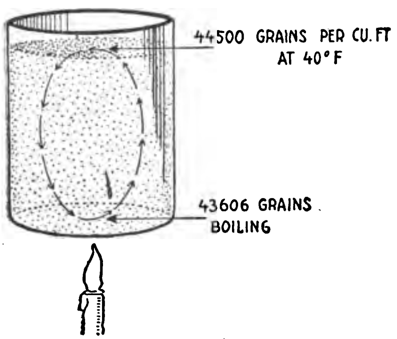


FIG. 58.—Why will water as it heats rise to the top of the vessel? Why will the water at the top sink?

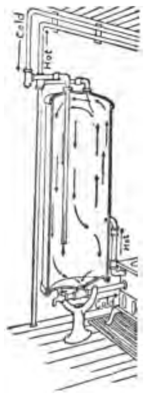


FIG. 58A.—Why is it possible to heat the water in the tank? Where will the hottest water be found in the tank?

the interspaces for air are lessened. To keep one warm in cold, windy weather the clothing should consist of loosely fitting garments, preferably of wool, except next the skin, with some outside wrap which is

nearly wind proof, such as very closely woven cloth, or leather or even rubber. A fur coat is much warmer if worn with the fur side inside.

Why Water Carries Heat.—Water at about 40° F. weighs about $62\frac{1}{2}$ pounds, or 436,961 grains, per cu. ft.; at boiling point water weighs 418,320 grains per cu. ft., or 18,641 grains *less*. That is, water weighs, on the average, about 108 grains less per cu. ft. for every degree F. it is heated. The reason is in the fact that the heating of water expands it, so that hot water is lighter, volume for volume, than cold water.

When water in any receptacle is heated at or near the bottom, the heated part of the water, being now lighter, will rise, carrying its heat with it. As already learned, this process of heat conveying is called *convection.*

In the construction of the familiar hot-water tank and "water back" of the kitchen stove equipment, the process of convection is usefully applied. *Look this construction up, and report.*

Why Air Carries Heat.—One cu. ft. of air weighs 0.07203 pound or 504 grains. For every five degrees the air is heated it weighs between 4 and 5 grains *less;* hence, heated air, being lighter than cold air, will rise, carrying its heat with it, and will float above the cold air,

Stated the other way round, for every 5 degrees that air is *cooled* it weighs from 4 to 5 grains *more* per cubic foot; hence, cooled air, being heavier, will sink beneath the warm air, buoying it up.

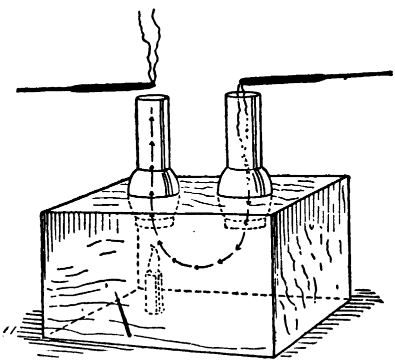


Fig. 59.—Is the smoke pushed or pulled down the chimney? Why?

Experiment to Show Convection by Air.—Arrange two chimneys over holes cut in the sides of a chalk box. Stand the box on its opposite side, and substitute a piece of glass for the cover. Place under one chimney a candle. Hold over the other chimney a smoking piece of Chinese joss stick, or of touch paper (look up *touch paper* in the dictionary). Why will the smoke go down this chimney? Why up and out from the other chimney? Why will the smoke not go down the latter?

Heating of a Room with a Radiator.—The steam heat is brought to the inside of the radiator by convection through pipes from the furnace

FIG. 60.—The arrows picture the circulation of air in a room, away from and toward a steam radiator. Why does the air over the radiator rise? If the hot air is rising why do you feel heat if you stand beside the radiator? Why does the air on the opposite side of the room fall and return toward the radiator?

FIG. 61.—By what process is this house heated?

in the basement. The heat passes from the inside of the radiator to the outside by conduction. The air, coming in contact with the radiators, in turn becomes heated, also by conduction. This heated air

rises, being pushed up by the cold air moving in toward the radiator. The warm air, on the ceiling, cools slightly and sinks, in its turn, coming in contact with the objects of the room and giving up heat.

Heating of Air by Convection.—Heating by hot-air furnaces is again more or less popular. The best location for air inlets has been found to be near the ceiling of a room. This system requires a fan to force the air into the rooms and insures fresh air, as well as heat, to all parts of the building. We shall learn more of this under the subject of *ventilation.*

The diagrams on page 179 give an idea of the movements of air for different positions of the inlets and outlets for ventilation.

Chimneys.—A chimney is used for two purposes; first, to create draft necessary to supply burning fuel with sufficient air; second, for the discharge of the noxious products of burning into the atmosphere at such a height from the ground as to render them innocuous.

The "draft" of a chimney depends upon the lessened weight of the air, when warmed, within the chimney at the bottom, compared with the same volume of air outside.

Refrigerators.—There are two usual types of refrigerators—top icing refrigerators and side icing refrigerators. They work on the same principle.

Fig. 62.—Why is the milk on the top shelf? Why will not the milk keep as well on top of the ice?

The air next to the ice becomes cool, and sinks through the bottom openings of the ice chamber into the main part of the refrigerator, while the warmer air from the upper part of the refrigerator enters the top of the ice chamber and is cooled. There is a continuous circulation of air past the ice and through the food chambers. This circulation is important because it distributes the cooled air to all parts of the refrigerator, and also because on passing the ice, the air loses some of the moisture and the odors which it has taken up from the food, especially that which is not yet cold. Therefore, anything which retards this circulation or stops up the openings of the ice chamber should be avoided.

The lowest temperature inside a refrigerator ranges from 44° F. to 57° F., and the highest from 64° F. to 72° F. This difference in temperature causes the circulation of the air in the refrigerator. By referring

to the diagram it will be seen that the air around the ice weighs more than the air above it.

It has been found that milk kept at 60° F. will develop in one day fifteen times as many bacteria as milk kept at 50° F. The same thing is true of many other foods. It is important, therefore, to find the coldest place in a refrigerator and use this place for foods, such as milk and meats, which need to be kept as cool as possible to prevent spoiling. The coldest place would naturally be directly under the ice.

Slow melting of the ice does not necessarily indicate a good refrigerator. Unless the ice melts it can absorb no heat, and would therefore be of little use in a refrigerator. Protecting the ice in a refrigerator by covering it up is a good way to save ice, but **a poor way to save food.** The proper way to use less ice is by using a refrigerator with better insulated walls, and by opening the doors as seldom and for as short intervals as possible.

Convection and Ventilation.—It will be seen from the work under convection that all our methods of obtaining pure air employ this process. Ventilation, and the amount of air required for each person, will be studied under that head.

How the Air is Heated.—The atmosphere is warmed by radiation, by conduction, and by convection. The air, being almost transparent, gets but little of the heat from the sun's rays as they pass through it. Those rays, as we have learned, when they strike the earth, yield heat. Some of this heat is radiated, warming the air near-by. This warmed air, rising, or moved by winds, carries its heat along (convection), dispensing it as it comes in contact with cooler air, or with cool objects.

Such dust and water vapor as happen to be in the air near the earth also get their little proportion of the radiant energy of the sun's rays.

Questions

1. What may make a fireplace smoke?
2. Why may a piece of burning paper held up the chimney stop the smoking?
3. Why will open windows "help the draft"?
4. Why are chimney-tops often covered with a stone flag, and openings left on two parallel sides beneath it?
5. Which two sides of the chimney should be left open?

6. Why do we have land breezes at night, and sea breezes during the day?

7. Why is there usually a "calm" about sunset?

8. What is observed rising over a hot radiator? Why does it rise?

9. What practical objection to placing a chimney on the outside of a house?

10. Which would be better for ventilation, a fireplace on the opposite side of the room from the windows or on the same side? Why?

11. Draw a diagram illustrating currents of air in a room warmed by a steam radiator.

12. Smoke from incense burning in a room was observed moving toward a lighted electric light bulb. Why?

CHAPTER V

EXPANSION AND HEAT MEASUREMENT

EFFECTS OF HEAT

Experiment to Show Expansion of Gas.—Fill a bottle half full of water colored with a little red ink; close with a one-hole rubber stopper through which runs a hollow glass tubing extending into the liquid. Place the hands on that part of the bottle which contains the air. The air will become warmer, expand, and force the liquid up the tube.

If air is heated 1° F., it expands $\frac{1}{461}$ of its volume. Suppose a room contains 3000 cu. ft. of air, and the temperature changed from 32° F. to 65° F., making a difference of 33°. The air would expand until there were about 3214 cu. ft. of air; that is, 214 cu. ft. of air would be forced out of the doors and windows.

Air is "gas." All gases expand when heated.

The Use of Expansion of Air in Cooking.—The expansion of air is an important factor in cooking. We beat our various baking mixtures, such as graham flour mixed with water or milk, to charge them with air, which expands when exposed to the heat of the oven, and renders the cooked product "light." Some cakes, as genuine sponge cake, are made light solely by the introduction of air in the vigorous beating of the eggs.

The "beaten biscuits" of the South illustrate how to make food light with no other aerating agent than air. The dough is beaten or kneaded, rolled or pounded, and folded over many times, until it contains a great deal of air.

Because a cold liquid contains more free air than a warm one, we use ice water to mix up pastry dough. The froth of well-beaten eggs is liberally aerated. Beaten in cool dishes and if possible, in cool places, the aeration is even more thorough, thereby insuring a better "lightening" when the product is placed in the oven.

Experiment to Show the Expansion of a Liquid and a Solid.—Fill a flask with a red liquid. Close the flask with a one-hole rubber stopper

through which extends a 2-foot piece of glass tubing with a very small bore. Mark the level of the liquid in the tube by sticking a bit of paper onto the tube there. Heat the liquid very slightly at first by allowing the flame merely to touch the flask for an instant. The level of the liquid will suddenly drop and then rise. Repeat the heating; the same thing will occur each time.

The glass is heated first, and the flask becomes slightly larger. The liquid will drop to fill up the extra space. Why does the liquid go back to the same level, and even higher after heat has been removed? Continue to heat the flask for a few moments. The liquid will rise quickly because of its expansion. One hundred pints of water will become 103 pints of water if heated from 39° F. to boiling point (about 212° F.).

The Expansion and Contraction of Water.—Liquids usually expand with heat. Water expands when *heated*, if started at a temperature above 39° F.; but if water, *cooled*, falls below 39° F. and the cold keeps increasing, the water will gradually expand until it freezes at 32°.

Expansion caused by Water Changing into Steam.—When water changes into steam exceptional expansion occurs. One quart of water will become about 1700 quarts of steam. When water at the boiling point, and the accumulating steam are confined, the tendency to expand persists, and the result is to create pressure, which keeps increasing if the heat continues to be applied to the water, and if the steam is kept confined. When the pressure becomes stronger than the walls of the container, the container will "burst," or explode.

But this expansive force of confined steam, when properly harnessed, is the propelling power of engines, locomotives, steamboats, etc.

Why Corn Pops.—A kernel of popcorn contains starch grains. The interior of the kernel is an aggregation of microscopic cells. The walls of these cells are sufficiently strong to withstand considerable pressure from within. Upon the application of heat, the moisture present in the starch in each little cell is converted into steam whose expansion bursts the cells, the explosion being sometimes startlingly loud. A very high degree of heat is required to pop corn in a satisfactory manner. This causes most of the cells to explode simultaneously. The grains of the corn are literally turned inside out, and are transformed into a relatively large mass of snow-white starch.

Why Ice Floats.—Water is at its heaviest when its temperature is 39° F., then weighing 62.424 lbs. per cu. ft. If any body of water,

whether a kettle of water or a lake, is at 39° F. and the water at the bottom begins to get *warmer* than 39° F., it will expand, grow lighter, and rise to the surface. But this is true also if the water becomes *colder* than 39° F. Growing *warmer*, from 39° F., water becomes lighter until,

Boiling water	at 212° F.	weighs 59.7 lbs. per cu. ft.
Water	at 32° F.	weighs 62.4 lbs. per cu. ft.
Ice	at 32° F.	weighs 57.5 lbs. per cu. ft.

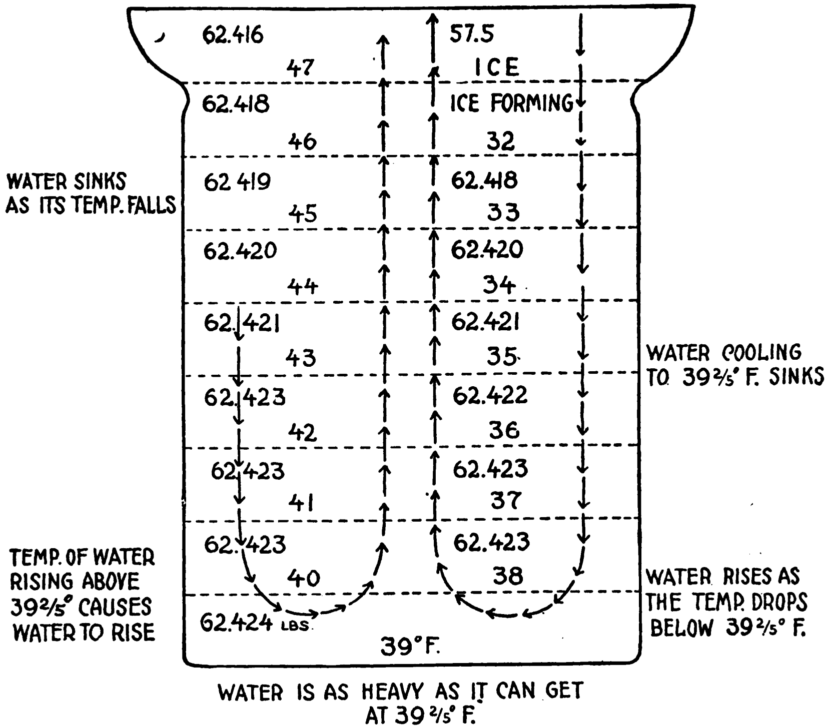


FIG. 63.—Why would ice float in boiling water? What is the difference between the weight of ice at 32° F. and water at 32° F.? At what temperature is water the lightest? At what other temperature is the weight of water about the same as that of boiling water?

at 212° F. it weighs 59.76 lbs. per cu. ft. Growing *colder*, from 39° F. it also becomes lighter until at 32° F. it weighs 62.416 lbs. per cu.ft., while yet liquid. But at that point, still water expands so suddenly that when changing to ice, its weight, as ice, diminishes to 57.5 lbs. per

cu. ft. though still at 32° F. Ice at 32° F. being lighter than water at any temperature, floats on water.

In deep lakes the water at the bottom will seldom reach a temperature either below or above 39° F.

FIG. 64.—When all the water in the lake reaches the temperature of 39.2° F., it is as heavy as it will become by loss of heat. As the water near the surface continues to lose its heat, it grows lighter and remains at the surface until changed into ice.

It appears by the diagram that water at 34° F. and water at 44° F. have the same weight. At what other degrees has water the same weight?

Water when freezing expands so rapidly that a cu. ft. of water at freezing point 32° F., changing from water into ice at 32° F., changes weight from 62.416 pounds to 57.5 pounds per cu. ft. That is, ice weighs about 5 pounds less per cu. ft. than water weighs at the point of freezing. If this expansion did not occur, ice would not float, but would sink to the bottom of our lakes and rivers, freezing solid all bodies of fresh water. Nowhere on the earth would the climate be warm enough even during the summer to thaw out the frozen waters.

Expansion of Metals and Solids.—With few exceptions metals and other solids expand with heat. Telephone and telegraph wires sag

FIG. 65.—Why has the top of the bottle been forced out?

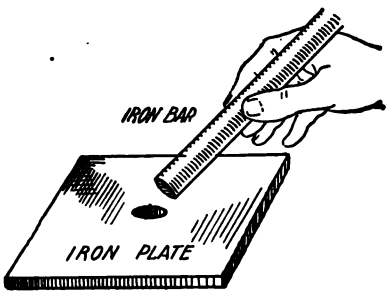


FIG. 66.

more during a hot day than during a cold day because of the extra length caused by expansion.

A mile of copper wire will be 100 inches longer on a hot day in summer than on a cold day in winter; a mile of aluminum wire 200 inches longer. The only material which does not expand with heat is rubber, which shortens; but its volume increases.

Illustration of Expansion.—Through an iron or brass plate (Fig. 66) at normal temperature a hole has been drilled just large enough to allow a rod of the same material at the same temperature to pass through. The rod when heated will no longer pass through the hole.

Melting Substances.—Most solids expand when melting and contract when returning to a solid; but cast iron, type metal, and water are examples of substances which contract on melting and expand when returning to solid.

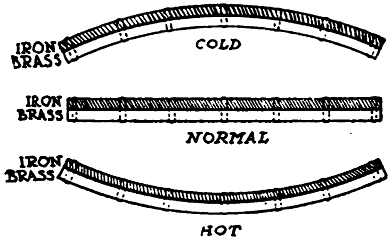


Fig. 67.

Difference in the Rate of Expansion of Different Metals.—All substances do not expand at the same rate. If straight strips of iron and of brass be riveted together to form a compound bar (Fig. 67), and heated, the bar will form an arc; and upon cooling the bar will revert to straight.

Why does the iron side become the inner side when hot? The outer side when cold?

Expansion in Incandescent Lamps.—One of the metals that can be used to compose the filament of an incandescent lamp that passes through the glass is platinum, since platinum and glass expand practically the same amount on being heated.

The platinum is sealed into the glass hot; the wire and glass contract equally, making a tight joint whether the bulb is hot or cold, thus allowing no air to reach the filament. Examine the place where the wires pass through the glass of an electric light bulb.

Questions

1. Why does the thermometer "drop" when first placed in hot water? Why "rise" when taken out.

2. Why do water pipes burst when freezing?

3. Why do little bubbles collect on the inside of a glass of water standing in a warm room?

4. Why should cool eggs which are to be used in an angel cake be beaten in a cold place?

5. Why do glass tumblers break when hot water is poured into them?

6. Why does paper or bread curl up when heated on one side?

7. Why does popcorn pop?

8. Why will it pop better if it has been in the ice box and is popped in a pan containing a spoonful of hot melted lard?

9. How does the weight of a cu. ft. of water at 34° F. compare with the weight of a cu. ft. of water at 44° F., at 38° F., at 90° F.?

10. Boiled water contains no air. Why will boiled water upon freezing cause a pipe to burst more quickly than water which has not been boiled?

MEASURING OF HEAT

Thermometers.—Because some metals and liquids expand equally for an equal amount of heating we are enabled to use them in combination to measure temperature. The usual kind of thermometer has a glass bulb on the end of a fine-bore glass tube. The bulb and part of the tube are filled with mercury, a vacuum is made in the remainder of the bore by removing the air, and the other end of the tube is so sealed as to preserve the vacuum. Mercury is used for high temperatures because, though it freezes at −38° F., it has the high boiling point of 647.6° F. Alcohol thermometers are used for low temperatures because, though it boils at 173.5° F., alcohol has the low freezing point of 202° F. below zero.

History of the Thermometer.—Previous to 1592 temperature was a matter of the comparison of one's personal sensations of heat and cold. In that year Galileo, an Italian, constructed the first thermometer. It was an air thermometer. It was not until 1700 that mercury thermometers were invented. The instrument most widely used for scientific work is the Centigrade invented in 1742 by Celsius, a Swede.

The Centigrade thermometer designates zero as the freezing point of water, and 100° as the temperature of the steam issuing from boiling water. The intermediate degrees are obtained by dividing the space from 0° to 100° into 100 equal parts. The spaces above 100° and below 0° are divided into degrees of that same width, and numbered accordingly.

The thermometer commonly used in this country is the Fahrenheit, invented in 1714 by a German of that name.

The Fahrenheit thermometer places the freezing point of water at 32° and the temperature of the escaping steam at 212°, the intervening space being divided into 180 equal parts, and the points above 212° and below 32° into degrees of that same size. The zero of this scale was found by noting the temperature of a mixture of equal weights of snow and ammonium chloride. Fahrenheit called this zero because he believed it (mistakenly) to be the lowest possible temperature, i.e., the entire absence of heat.

While Fahrenheit and Centigrade thermometers are the more generally used, the Réaumur scale is used to no small extent in Germany and Russia, though now being superseded by Centigrade.

The Réaumur scale has freezing point at 0°, the boiling point at 80°, with 80 equal spaces between and without these points on the scale. In the original Réaumur thermometer alcohol was used instead of mercury.

For extremely high and low temperatures a Hydrogen Gas thermometer is used, somewhat similar in principle to Galileo's original instrument for recording heat.

The relative values of the degrees on the different thermometers are given in the following table:

THERMOMETRIC SCALES

Data Determined.	Fahrenheit.	Centigrade.	Réaumur.
Degrees between freezing and boiling	180	100	80
Temperature at freezing point.......	32	0	0
Temperature at boiling point.......	212	100	80
Comparative length of degree.......	1	$\frac{9}{5}$	$\frac{9}{4}$
Comparative length of degree.......	$\frac{5}{9}$	1	$\frac{5}{4}$
Countries where used..............	England and America	France and Germany	Russia

$$F. = \tfrac{9}{5}C. + 32° = \tfrac{9}{4}R. + 32°. \qquad C. = \tfrac{5}{9}(F - 32°) = \tfrac{5}{4}R.$$

Use of Thermometers.—The measure of temperature is important. People for many ages have measured heat roughly. Testing the heat of a flatiron with the moistened finger and testing the heat of the oven with a piece of paper are familiar illustrations. The thermometer on the oven door (metallic thermometer) has taken the place of the paper.

Many lives are now saved that would be sacrificed were the old unreliable method of taking temperature by feeling the brow or the hand

still in vogue. The Clincial Thermometer tells of the fever, present or approaching.

If the thermometer registers 100° F. the fever is slight; at 102° F. the fever is rising; at 103° F. it is serious; at 106° F. the condition is alarming, as over this temperature the disease may prove fatal.

FIG. 68.—A clinical thermometer in a case with attached cover.

Bath thermometers are useful, as one may regulate the temperature of the bath to that best suited to the individual need.

Cool bath, 66° F.; cold bath, lower than 60° F.; temperate bath, 78° F.; tepid bath, 86° F.; normal temperature bath, 98° F.; hot bath, 105° F.

Maximum and Minimum Thermometers are ingeniously constructed so that a sliding indicator on one of two tubes stops at the lowest temperature had since the previous reading, and a similar device on the other tube stops at the highest temperature had since the previous reading.

FIG. 69.—Bath thermometer.

This type of thermometer is serviceable, even necessary, in the sickroom, the greenhouse, and in many other circumstances.

No home should be without a reliable thermometer. An ideal temperature for indoors is 68° F. From 70° to 75° is progressively conducive to ill health.

Temperature.—Certain fixed temperatures serve as starting points. For example, objects are "warm," "hot," "cool," or "cold," compared with the body temperature. We say a thing feels cold to us if it is cold to the touch; warm, if warm to the touch. The normal temperature of the human body is about 98.6° F.

The lowest temperature obtainable is called **absolute zero.** This would be a point 459.6° below zero Fahrenheit, or 273.1° below zero Centigrade. At this temperature heat, as we use the term, would be non-existent.

Temperature, Btu. and Calorie.—The word *temperature* is a word of Greek origin, meaning "to measure heat." Not the amount of heat, but the degree of heat is implied. Naturally, a greater amount of heat is required to heat a barrel of water than to heat a quart of water—from, say, 60° F. to 80° F.; in fact, 125 times as much heat.

The *degree* of heat is measured by the *thermometer*, and the *amount* of heat by the *B. T. U.* (British Thermal Unit); a **Btu.** being the amount of heat necessary to heat 1 *pound* of water 1° F.

The **Btu.** unit is used in the United States and in England. In many of the other countries heat is measured by the **calorie,** which means the amount of heat required to heat 1 gram of water 1° C.

Experiment, with Problems.—Place a pound of water in a large dish and 1 gram of water in an evaporating dish. Heat both to boiling point after taking the temperature of the water in both dishes. What thermometers would you use? How many Btu. would be required to heat the pound of water? How many calories to heat the gram of water? How many calories would be required to heat the pound of water to boiling?

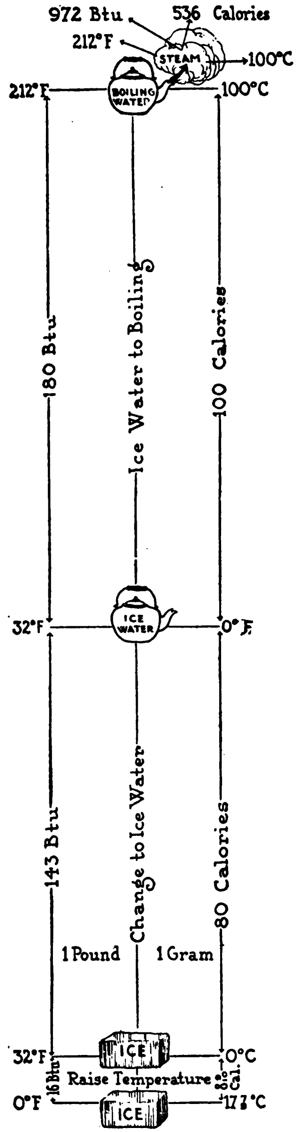
Latent Heat.—Ice has the same temperature as ice water, namely, 32° F. One might think the ice colder than the water, but if a piece of ice is placed in a dish and allowed to melt, the temperature of the mixture will presently be 32° F. or 0° C., and will remain so while the ice is melting. This shows that a great deal of heat is used to melt the ice but without raising the temperature. The heat which is used to melt the ice is called **latent heat** (hidden heat).

Ice melting in the refrigerator takes heat from the food and air of the box. This heat is in the resulting water, and goes out from the box with it. Out from the air and food in the refrigerator 143 Btu. go into the melting of each pound of ice, and then escape from the box in the dripping ice water.

It is the other way round when water congeals: Out from the water 143 Btu. go into the surrounding atmosphere, for each pound of water which freezes.

Experiment—Put a small amount of ice water in an evaporating dish. Heat the water to boiling point, noting the time required. Boil the water until it has all changed to steam. noting the time required. Report to the class.

The time required to boil the water away being about five times as long as to heat the water from freezing point to boiling, we infer that about 5 times as much heat went into the steam as into the water from



To Heat 1 Gram of Steam From 100°C to 200°C Requires 47.7 Calories

freezing point to boiling, despite the fact that the temperature of steam and boiling water is the same (about 212° F.).

Sensible Heat.—To change 1 pound of water into steam requires 970 Btu., and to raise the temperature of 1 pound of water from freezing point to boiling point requires 180 Btu. Heat which will affect the temperature is called *sensible heat*. Again, the heat that goes into the changing of a liquid into a gas becomes what we have already called *latent heat*.

Heat Produced by Solidification.—Tubs of water are sometimes placed in cellars to prevent vegetables from freezing. As the temperature of the cellar falls, it is the water first which begins to freeze. In so doing it yields to the air heat enough to prevent the air from falling as far below the freezing point as it other-

FIG. 70.—How much heat is used to melt ice? What is the temperature of the ice while it is melting? What is the temperature of the water after the ice is melted, i.e., of ice water? How much more heat has a pound of water at 32° F. than ice at 32° F.? How much more heat has a pound of steam at 212° F. than a pound of water at 212° F.?

wise would. Heat continues to be given out by the water as long as the freezing goes on.

Specific Heat.—Not all substances require the same number of Btu. to heat 1 pound of the substance 1° F. or 1 gram of it 1° C. The amount of heat required to heat 1 pound of water 1° F., of 1 gram of any substance 1 ° C., is called the *specific heat* of that substance. It takes less heat to heat 1 pound of tin 10° than it does to heat 1 pound of water 10°, i. e., the specific heat of mercury is not so great as that of water.

It is because mercury is so susceptible to heat that it makes so valuable a substance for thermometers.

TABLE OF SPECIFIC HEAT

Water	1.00	Sand	.19
Copper	.091	Olive oil	.31
Alcohol	.62	Wood	.65
Iron	.113	Lead	.031
Soapstone	.21	Glycerin	.55
Glass	.198	Marble	.21
Aluminum	.214	Salt	.17
Tin	.055	Brick	.2
Limestone	.217	Marble	.215
Mercury	.033	Air	.238

From the table it will be seen why soapstone discs are used in fireless cookers instead of iron discs.

Experiment to Show Specific Heat.—Heat in boiling water several pieces of different metals of the same weight. Take several cans of the same size and material and containing each the same amount of water at a uniform temperature. Into each can drop one of the heated pieces of metal, and see which warms the water the most. That metal has evidently the highest specific heat of the metals used.

Melting and Solidifying.—Different substances melt at different temperatures. For example ice melts at 32° F., butter at 91.4°. The **melting** point is also called the **fusion** point. The reverse of this process is called freezing or solidifying. Nearly all substances remain at the temperature of their melting point until completely changed into a liquid. But a few substances, such as sealing wax and butter, continue to become warmer as they melt.

Impurities affect the *melting* point. Salt is often used to melt ice, as the presence of salt causes the ice to melt at a lower temperature. This necessitates extra heat,

and much of the extra heat is drawn from the freezer and its contents; and, presently, so much of the heat has been drawn from the contents (the cream mixture), that that solidifies, becoming the familiar ice cream.

Impurities in water, such as salt, also produce a low *freezing* (solidifying) point.

Fig. 71.—Pipes on the ceiling are provided with automatic sprinklers.

Fig. 72.—The heat of the fire melts the alloy plug.

Fig. 73.—The water is freed and sprays the fire.

Fig. 74.—Such devices may prevent great losses.

Alloys.—An alloy is a homogeneous compound of two or more metals. The melting point of some alloys is so low that they are of great value as fuses.

Electric fuses, and plugs for boilers are easily melting alloys.

Automatic fire sprinklers, used in many buildings to extinguish fires, use an alloy which melts quickly at a low temperature.

The heat of the fire melts the alloy plugs in the ceiling water pipes, allowing the water to spray room and contents.

Questions

1. Why do objects, which ordinarily feel cold to us, feel warm when our hands are cold?
2. When is a pipe hot, warm, cool, or cold to you?
3. Why do we blow on our soup to cool it, and on our hands to warm them?
4. Why is it poor policy to cover ice in a refrigerator with paper?
5. On what theory do vegetable men often place tubs of water near their vegetables in the cellar to keep them from freezing?
6. Why will running water seldom freeze?
7. Why does the bottom of a kettle on a fire never melt when water is in it?
8. Why is water used in the radiator of an automobile?
9. Why will steam heat warm a room more quickly than hot-water heat?
10. Why may the air over a lake be warmer when the water is freezing than when the ice is melting?
11. Why is it warmer during a thunderstorm than directly after?
12. When and why is alcohol added to the water in the radiator of an automobile?
13. Why do two pieces of ice stick after they have been squeezed together?
14. Why is a burn from steam at 212° F. so much more severe than a burn from boiling water at 212° F.?
15. Why are hot-water bottles better for warming a bed than soapstone discs or flatirons?
16. Why should thermometers for determining temperature of rooms be about 4 ft. from the floor, away from openings and on a wall not exposed to the outside air or near source of heat?
17. What is the temperature of the body in degrees C.?
18. What is the temperature of the schoolroom in degrees C.?
19. Why does the water in fruit and vegetables freeze less readily than water in pans?
20. What parts of Chap. V impress you most? Why?

CHAPTER VI

OXIDATION AND ITS RELATION TO LIFE

BURNING

The Discovery of Fire.—There was a time in the history of the race when fire was not known. There are many ways in which it may have been discovered—from lightning, from volcanoes, from spontaneous combustion, or from oil-wells, some of which have burned for hundreds of years after being set on fire.

Fire and Civilization.—The primitive savage learned to cook his food, to get warmth for his crude home, and to have a light as a protection during the long, cold nights when wild beasts were on all sides ready to devour him.

Next, fire became of interest in the home. People gathered around the hearthstone, and became more social. To-day the social world owes much to fire and its resultant forces—steam, which furnishes power for our boats, trains, and lighting systems; and heat, which is so important in every phase of life.

Cause of Burning.—Place a lighted candle in a dish containing about 1 inch of water. Invert over the candle a tall olive bottle, standing in the water.

The water will slowly rise a few inches in the bottle, the light will go out.

Something has caused a partial vacuum in the bottle, thus allowing the water to be pushed up into the bottle. Something which caused the candle to burn has gone, the light having gone out before the vacuum was complete enough to raise the water to the level of the flame. The part of the air subducted, and which had caused the candle to burn, was **oxygen.**

Experiment with Oxygen.—Fit a zinc shelf into a deep " cake tin " by bending a zinc strip about 3 or 4 inches wide so as to allow the shelf inside to be about half as high as the sides of the cake tin. Drill a hole through the center of the shelf and two

small holes on each side of the center hole. Fit a one-hole rubber stopper through the hole. Extend a glass or metal funnel through the stopper so that the bowl of the funnel is toward the bottom of the tin. The stem of the funnel must not protrude above the shelf more than $\frac{1}{4}$ inch.

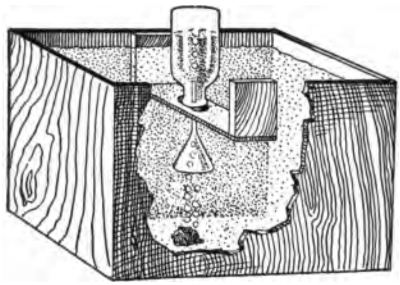


FIG. 75.

Pour water into the tin until the level shall be $\frac{1}{2}$ inch above the shelf level.

Fill a bottle with water. Cover it with a piece of glass and invert over the funnel stem and (now withdrawing the piece of glass) stand the inverted bottle of water on the shelf of the cake tin, which we now call a *pneumatic trough*. Be sure the bottle is full of water, with no bubbles present. Place under the funnel (called a *bell*) a small piece of fused **sodium peroxide**. The gas which rises to replace the water is **oxygen.**

The two holes will allow the water to escape from the inverted bottles as the oxygen enters.

Light a soft-wood splinter. After it has burned a moment, extinguish the flame, leaving the spark glowing on the tip. Insert the glowing splinter tip in the bottle of oxygen, placed right side up on a table. What happens will show something about the power of oxygen to make things burn.

The oxygen itself does not burn, as the splinter may be removed, blown out, and reinserted several times, taking fire each time without setting the gas (oxygen) on fire.

So active is this gas that iron wire may be made to burn in it. Insert into the bottle of oxygen a piece of picture wire on which there is a little burning sulphur; or the tip of the wire may be heated red hot in a fire or flame. The wire should burn brilliantly.

Oxygen in the Air; Nitrogen.—Air is not entirely oxygen. There was much of some gas in the bottle after the candle went out (experiment, page 91). About one-fifth of the air is oxygen. The remaining part of the air is chiefly *nitrogen.* The air of the atmosphere contains also some water and a little dust. A trace of a gas called Argon is also present. **Nitrogen** is a gas which will not burn or make things burn; by its presence too large a percentage of oxygen in the air is obviated.

Oxidation.—Oxygen unites with any material present which is burning. Whenever oxygen unites with a substance, the substance is

said to **oxidize.** Rapid oxidation is called **burning** or **combustion,** and is accompanied by heat, and, under certain conditions, by light. When the food in our body oxidizes, giving us the necessary heat to maintain life, the process is called **wet burning.** Sometimes oxygen unites so slowly with substances as to give off little heat at any one time. This slower process is called **slow oxidation.**

Whenever oxygen unites with a substance, the resulting compound is called an *oxide.* When iron rusts, the iron and oxygen unite; the resulting rust is oxide of iron.

It is believed that nearly all the colors in nature are due to different forms of iron. Different compounds of iron give the colors of blue, green, red, and brown.

Spontaneous Combustion.—Heaps of cotton waste soaked in oil slowly oxidize, giving off heat. The kindling point, with such mixtures, is low, and if the heat reaches the kindling point, fire results. Such fires are said to be caused by **spontaneous combustion.**

The Production of Light and Heat without Oxygen.—Burning, then, means a rapid combining of oxygen with other substances, usually with the production of heat and light. Unless oxygen is present, burning cannot take place. Substances may glow, as in an electric light bulb. The filament becomes very hot, but does not oxidize or burn.

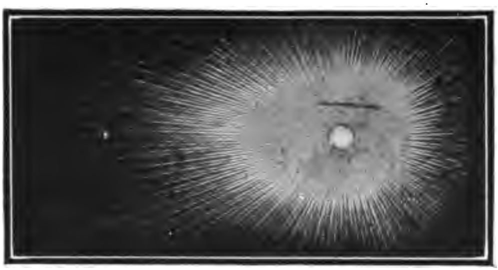


Fig. 76.—The earth's tiny share of the sun's heat.

Scientists have come to the conclusion that there is no oxidation in the sun; that the sun is not burning up but glowing, and that the heat results from its constant shrinking (page 61). So great is the weight of the sun (1,980,000,000,000,000,000,000,000,000 pounds) that the pressure from the shrinkage is sufficient to cause inconceivably intense heat. The sun is about 1,300,000 times the size of the earth.

Radium and other elements are supposed to assist in the producing and dispensing of the heat.

Oxygen in Other Things.—The amount of oxygen in the rocks a few feet below the surface of the earth equals the amount of oxygen in the air above them. Oxygen is in water, food, sand, clay, gravel, wood and in the majority of substances which we use every day—not free oxygen, as in the air, but combined with other substances.

Prevention of Oxidation.—Many methods have been tried for preventing oxygen from uniting with substances. Painting wood, iron, etc., is the usual method; or shellac, lacquer, and other preparations may be used.

Rapid oxidation, or burning, is often prevented by applying water, thus diminishing or excluding the supply of oxygen. Besides, the water lowers the temperature, and if it changes to steam, may cover the material with a thin film of water and water vapor—an action which prevents oxygen from contact with the burning material.

Water cannot be used to extinguish the flame of burning oil because oil floats on water, thus keeping in contact with the air and continuing to burn.

There are some gases, like nitrogen, which do not support combustion. These gases are used in fire extinguishers, whose effect is to smother the burning material with inert, non-combustible gas, thus preventing contact with oxygen.

The ordinary fire extinguisher uses a gas called "carbon dioxide." Another type of this kind of fire extinguisher contains material which forms bubbles or foam, by which oil fires are extinguished easily, as the bubbles prevent air reaching the surface of the oil.

Fig. 77.

Kindling Temperature and Matches.—Substances which burn have a definite temperature at which they will start burning. Not all substances start to burn at the same temperature. Paper, wood, sulphur, phosphorus, etc., have different kindling points. The match is an example of the use of different substances with different **kindling** points.

Matches are made by soaking one end of a piece of wood in paraffin and then dipping this in a mixture of glue, phosphorus, and a material which gives off oxygen, such as potassium chlorate. Some matches are made with powdered glass, zinc oxide, rosin, glue and coloring matter. Safety matches have the phosphorus on the box so that the matches will not take fire inside the box.

Experiment. To Boil Water in a Paper Bag.—Take a square piece of paper and fold it so as to form a conical bag as shown in Fig. 77. Suspend the bag by strings and, pouring water into it, allow the flame of an alcohol lamp or Bunsen burner to fall on the bag, being careful to prevent the flame from touching the paper in any place where there is no water. The water can now be heated until it boils, without the paper being burned, because the paper cannot be heated much more than 212° F., and this is not sufficient to burn it, since the kindling point of paper is higher than the temperature of boiling water.

Questions

1. Why may damp hay in a barn take fire?
2. Why must one be careful not to throw in a pile the waste and rags which have been used about an automobile?
3. Overalls which are oily will sometimes take fire if thrown in a heap on the floor and left for a long time. Why?
4. Why will hanging the oily overalls on a nail prevent spontaneous combustion?
5. Why must wood fires be arranged loosely in order to burn well?
6. Why does baled cotton or piled sawdust smolder if on fire?
7. How are fires extinguished in a ship's hold?
8. Why should a person with clothes afire not run out-of-doors?
9. What is the best way of extinguishing the flame when one's clothes take fire?
10. Why will a burning match go out if covered with the foot?
11. Why should not water be used on an oil fire to extinguish it?
12. What is the best method of preventing oxidation of a house, iron, brass?
13. What is the best method of putting out a fire in a room?
14. What would you do if the lace curtains caught fire?
15. When one stops all night in a hotel what precautions should be taken as to fire?
16. Find out the fire requirements of your town regarding inflammable oil, fire extinguishers in public buildings, school fire drills, etc.
17. Is your school living up to the requirements? Insist that it does. This is a part of good citizenship.

GAS AS A FUEL

Parts of a Flame.—If a sheet of cardboard is held in a candle flame or gas burner, the paper will be scorched in the shape of a ring, the middle of the ring being unburned. Run a pin through a match, near the head, and place it carefully upright in the center of a Bunsen burner. Light the burner. The match will not take fire in the colorless cone at the center of the flame. This part of the flame is made up of unburning gases. Hold a piece of glass tubing in the inner cone in such a manner as to allow the gas to run through the tubing. Light the gas outside of the flame at the other end. This inner cone is made up of unburning gas which diffuses outward to the air. Around this is a second cone in which oxygen unites with the gas, setting free small particles of carbon which are heated to "white heat." Around this second cone is a third cone, bluish in color, where complete combustion is taking place. If a large quantity of air is allowed to enter the Bunsen burner a non-luminous flame is produced, with an inner cone of unburning gas, and an outer cone of gas where complete combustion is taking place, resulting in a colorless flame.

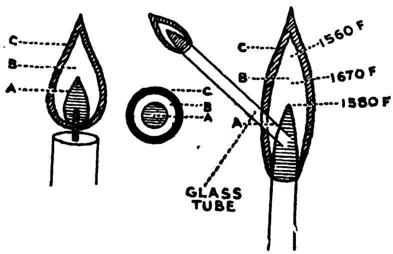


FIG. 78.—Parts of a Flame.

The Action of Wire Gauze upon Gas.—Place a piece of fine copper wire gauze over a small gas flame. It will be seen that the gas above the wire gauze does not take fire until the gauze has become red hot. Turn out the gas. Allow the gauze to cool; replace it about 1 inch above the burner, and light the gas above the gauze. The gas will burn on top of the screen and will not take fire underneath, since the heat is rapidly conducted away by the wire screen, preventing the gas from reaching the temperature of kindling point.

There are two uses made of this principle. One is in the Davy Safety Lamp in which the flame is enclosed in a screened cylinder. This enables miners to go into a mine without danger of exploding the fire damp (a gas found in mines), since the gas can burn only as fast as it can sift through the screen. A screen is also used in

the Bunsen burner or mantles to prevent the gas from burning back. Often in lighting a gaslight the mixture of air and gas is sufficient to cause a slight explosion which may cause the gas to take fire at the spud or base of the burner. The gauze helps to prevent the gas from taking fire at this point.

Explosions.—When air is mixed with an inflammable gas, and the temperature is raised to the kindling point of the gas, an explosion takes place. The gas expands so suddenly, sometimes, and with such force as to blow walls or buildings apart. If there is a large amount or a very small amount of gas present in the air, the mixture will not explode. The proportion of air to gas in an explosive mixture varies, but in general it ranges from about 5 to 12 parts of air to one part of gas.

The gas of gasoline explodes when 1.5 to 3 per cent of gas is mixed with air. Kerosene poured upon a burning fire often produces disastrous explosions because the gas and air may happen to be mixed in the right proportions. Explosions in mines are due to the same cause.

There are usually two sounds to an explosion, one caused by expansion, and the other by the air rushing in. The two sounds occur so close together as to give the impression of one.

Hydrogen.—Hydrogen is a colorless, odorless gas which burns with a blue flame, if pure. The gas is a constituent of coal, and of many other valuable compounds, such as water, hydrogen peroxide, acids, sugars, starches and many of the foods. As hydrogen gas is very light, it is of great value for filling balloons.

Hydrogen mixed with air is very explosive. It affords one of the best examples of a gas exploding when mixed with the correct proportion of air.

Hydrogen gas may be made by placing a small amount of zinc in a generator (Fig. 79) and adding hydrochloric acid and water.

Fill one bottle with water, another half full, and put but a small amount of water in a third. Arrange a gas generator as shown in the diagram. Over the water collect the gas in the three bottles until no water is left in either.

Test each bottle (placed right side up) with a lighted taper. Note what happens to:

1. The bottle of pure hydrogen.
2. The bottle half hydrogen and half air.
3. The bottle mostly air, with the slight admixture of hydrogen.

Burning of Gas.—Light a candle. After a few moments blow it out and hold a lighted match in the stream of gas a little way from the wick. The vapor will take fire, carrying the flame to the wick. This vapor gas can be made to burn at some distance from the flame; thus:

Place the candle in a lamp chimney which has props under the chimney to allow the air to enter. Carefully blow out the light, or extinguish it with a piece of glass tubing. Allow the "smoke" or "gas" to rise to the top of the chimney. Light it with a match. The flame will burn down to the wick and relight the candle.

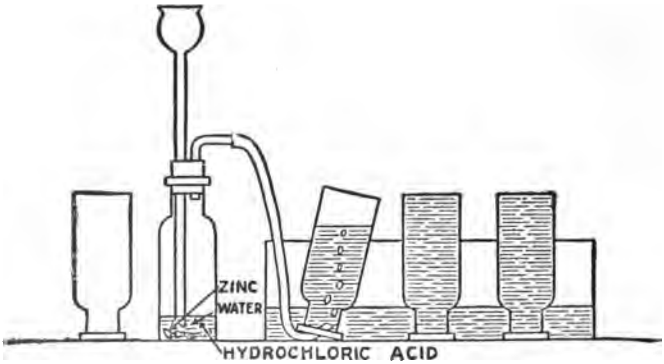


FIG. 79—Apparatus for Getting Hydrogen.

The candle may be called a gas generator. The wax does not burn, but melts where the wick extends out of the wax. A hollow formed there holds this melted wax which is drawn up the wick by a process known as *capillarity*. More about capillarity, later.

When, in the candle experiment above, the liquid wax reaches by capillarity the upper part of the wick, the heat there changes it to a gas, and it is this gas which burns. This suggests the inflammability of gasoline vapor. *The vapor or gas of gasoline has been known to take fire from a flame* 50 *feet from a person cleaning clothes.* The gas of gasoline is much heavier than air, and the fire will travel along the stream of gas to the vessel containing the gasoline.

Kerosene burns just above the liquid, at which position there is a gas and plenty of oxygen to keep it burning.

Heat a few pieces of wood in a test tube until gas forms. Light the gas. Do the same with paper, sugar, starch and soft coal. Notice the gas burning over a wood fire in the fireplace.

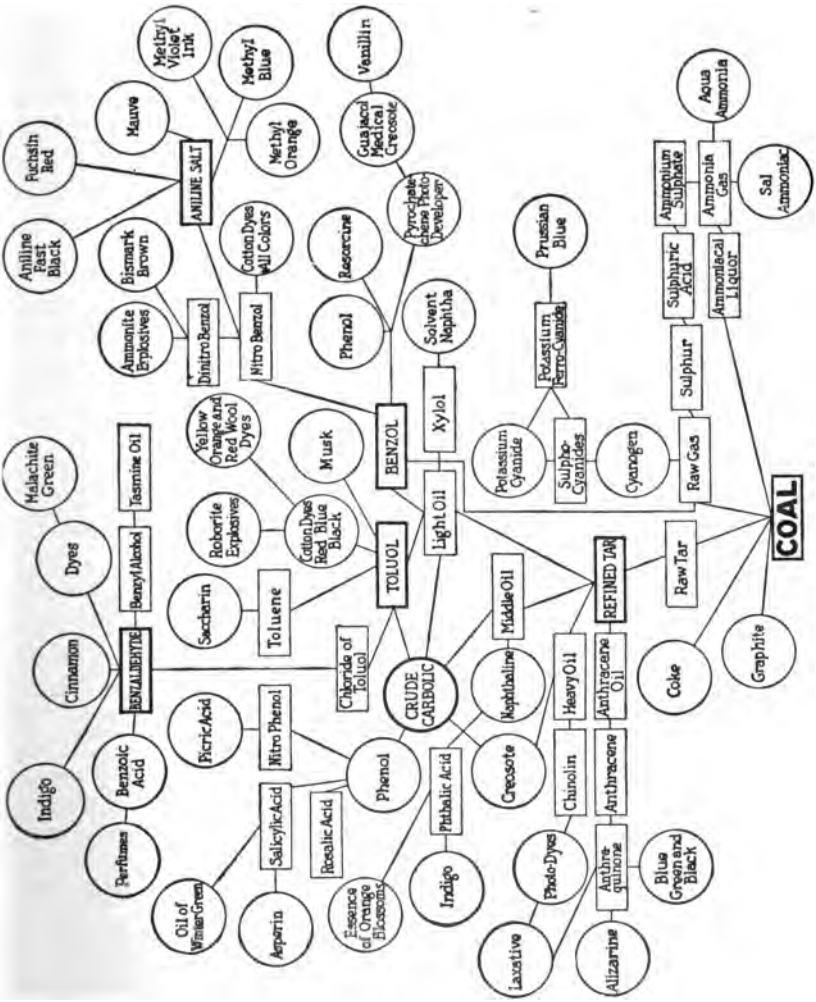


FIG. 80.—Coal is a precious mineral. Dyes, explosives, drugs, perfumes, flavors, ammonia, oils, are some of the products obtained by direct and indirect distillation of coal. With how many products of coal are you familiar?

Coal Gas.—Coal gas is generated from bituminous coal. The gas is used chiefly for lighting, heating, and cooking.

The products obtained from a ton of good coal are about

10,000 cubic feet of gas;
1,400 pounds of coke;
120 pounds of tar;
20 gallons of ammonia.

The coke is used to heat the bituminous coal or is sold as a fuel. Tar is used for tarred paper, paint, preserving lumber and wood pavings. Benzine and gasoline are extracted from it. Oils, dyes, flavors, perfumes, material for moth balls and many other useful products are obtained from tar. (Examine Fig. 80, and its legend.)

Measurement of Gas.—The gas used in the household is usually measured on the premises by a gas meter. In the United States and parts of Europe the so-called dry gas meter is most commonly used for this purpose. There are a number of different types of dry gas meters in use, which, while differing considerably in external appearance and design of parts, operate on the same general principles.

Gas Meter Index and How to Read It.—Gas meters are provided with an index. The top dial of the index is called the test dial. One revolution of the test hand indicates that 2 cu. ft. of gas have passed through the meter.

Of the large dials the first one at the right is usually marked "1 thousand." This means that during one revolution of the hand 1000 cu. ft. of gas have passed through the meter. The dial is divided into ten equal parts so that the passage of the hand over each part indicates the passage of $\frac{1}{10}$ of 1000 cu. ft., or 100 cu. ft.

If the first dial is marked 1 hundred, the second dial will be marked 1 thousand, the third 10 thousand and the fourth 100 thousand, etc.

The reading of the index in the illustration is as follows:

Reading of 1 thousand dial............	200 cubic feet
Reading of 10 thousand dial............	4000
Reading of 100 thousand dial............	80000
Complete reading of the meter........	84200

The amount of gas consumed for one month is obtained by subtracting the reading of the meter for the last month from the reading of the meter for the present month.

Prepayment Meters.—These meters are so constructed that one can insert a coin and receive a certain amount of gas. After this is used the meter will automatically cut off the supply of gas until another coin is inserted. Most prepayment meters are so constructed that when the gas paid for is nearly used, the supply of gas will be gradually shut off, thus giving the consumer a chance to insert another coin before his supply of gas fails entirely.

The sudden shutting off of the gas supply would be not only inconvenient but *dangerous*, for if one should forget to turn off his burner the insertion of another

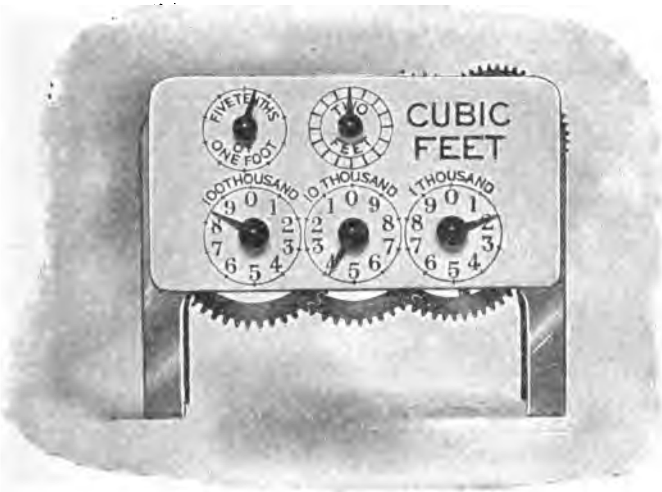


FIG. 81.

coin into the meter would allow gas to escape through the still open burner into the home. Even when the meter does shut off the supply of gas gradually, lights go out and many accidents result. There is *considerable danger* in the use of prepayment gas meters.

Cost of Gas Consumed per Hour in Appliances.—One may easily determine the cost per hour of any gas-consuming appliance.

Shut off all gas appliances which consume gas through the meter. Turn on and light the gas for the appliance whose consumption of gas you wish to measure. Record the number of times the test dial revolves per minute. It is usually better

to make several tests for several minutes and take the average. Multiply the number of cu. ft. or parts of a cu. ft. by 60. Why?

Determine the cost of gas per 1000 cubic feet from your gas bills, or from the company. Compute the cost of the gas consumed per hour by the gas appliance.

Error of Gas Meters.—Gas meters may be slow or fast. Meters of well-conducted companies are usually kept in order, but it does happen that serious errors occur in gas meters.

A consumer should check up his meter occasionally. He should read his meter as nearly as possible at the time when it is read by the gas company, and check the consumption with the gas bill, to prevent errors which may occur in the office of the company.

Leaks cause a great loss of gas at times. The consumer may check his meter by turning out all gas-consuming appliances and watching the test dial for several minutes. If there is a leak the dial will register and the amount of gas lost per hour or day may be computed.

If a consumer's bill for a certain period of time greatly exceeds that of a previous period the reason may be:

1. An increase of gas consumption;
2. An error of the gas company in reading the meter;
3. An error in the office work;
4. A fast meter;
5. A leak.

Tubular Connections for Gas Fixtures.—Leaks dangerous as well as costly often occur, not only through loose joints, but also through poor connecting hose or tubes. The wise consumer will have reliable equipment.

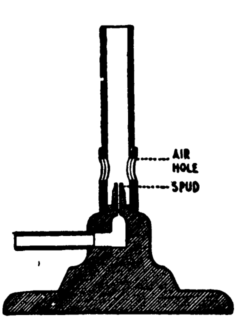


FIG. 82.

Burners.—For lighting, heating, and cooking, the Bunsen type of burner is chiefly used. The burner consists of these parts:

1. The barrel, a metal tube through which the gas passes. At the foot of the barrel there are two or more holes to allow air to enter.
2. A ring or device to open or close the holes.
3. A base, containing a small central gas way—called a "spud."

Gas enters at the base, passes through the spud and through the barrel, forming a **partial vacuum.** Air enters the holes near the base, and mixes with this gas. When the holes are

partly open, air enough enters to produce a non-luminous flame. When less air enters the holes near the base, the flame will be luminous.

Questions

1. Why should one avoid cleaning clothing with gasoline in a room where there is a fire?
2. Why will a match go out without setting kerosene on fire if thrust down into the liquid quickly?
3. Why do kerosene lamps have wicks? Candles?
4. Does the wax of the candle burn? Prove your answer with a match.
5. Why do some cities forbid the sale of gasoline in open cans after sundown?
6. Why should gas burners be well adjusted?
7. Why will a match go out if the match is held in such a position that the burning head will be above the wood?
8. Why may a candle be considered a gas generator?
9. Why does a candle or lamp smoke for a moment after being blown out?

OTHER FUELS

Water Gas.—Water gas is used in some cities as an illuminant. As water gas is very poisonous, great care must be taken to prevent its escape into the room.

Natural Gas.—In many regions a cheap and convenient gas is obtained from the earth. Natural gas is a result of the great heat within the earth acting upon the vegetable and animal matter at great depths. Wells are drilled into the earth, and the gas piped to the consumer.

Acetylene Gas.—This gas is especially rich in carbon, and gives an intense white light. It is very explosive when mixed with air, and because of its richness in carbon as well as for safety, a special burner is required.

Gasoline.—Besides its uses in engines, and for cleansing, etc., gasoline is used for lighting and cooking. The burners are so constructed that the liquid gasoline is converted into a gas at just the right point for the gas, not the liquid, to burn as a flame.

Gasoline vapor is very explosive if mixed with air. Accidents have occurred through trying to fill the "tank" when the stove was lighted. The modern gasoline stove is so constructed that the tank cannot be filled while the stove is lighted.

Gasoline Engine.—The gas of gasoline is used in gasoline engines because of its explosiveness when mixed with large quantities of air. The gasoline is caused to enter a *carburetor* where it is changed to a gas and mixed with air. From the carburetor the gas enters the cylinders of the engine, and is exploded by means of electric sparks furnished by a storage battery, or by an electric appliance set in motion by the mechanism of the engine when started.

Alcohol as a Fuel.—One part of grain alcohol will give the same amount of heat as two parts of wood alcohol. It is more economical to use denatured alcohol, which is largely grain alcohol, as a fuel than ordinary wood alcohol.

Coal.—Coal beds were once great swamps in which trees and plants had fallen and turned into coal. Some of the trees were very different from those of to-day. Fossil trees found in the coal mines tell us the trees must have been in some cases 40 feet in diameter, and tall in proportion. Coal is divided into two general classes:

1. **Anthracite,** or hard coal, which ignites with some difficulty, but burns slowly with intense heat.

2. **Bituminous** coal, or soft coal, which ignites readily and burns easily, if there is a good draft. Soft coal should be put on the fire in small quantities. If put on too freely the gases escaping from the too abundant coal may not all burn, causing a great deal of smoke and wasting valuable heat.

Two gases form during the burning of coal, carbon dioxide and carbon monoxide. The carbon monoxide is formed in the lower part of the fire, rises to the top and is seen burning with a blue flame at the top of the coal fire. If there is not sufficient air at the top of the fire, some of this gas escapes up the chimney, or into the room unless the drafts are properly adjusted. People have often been killed by this gas escaping into a sleeping room during the night, as the result of wrong adjustment of the drafts.

Cannel coal is rich in volatile matter. It is compact in texture, and has an oily appearance. Kentucky, Indiana, and Ohio furnish a small supply of this coal.

Peat.—In Ireland and in the United States there are great bogs in which trees and plants are decaying every year, forming a thick black

mud called **peat.** In wet places the peat forms rapidly. Roman coins left in the British Isles by the soldiers 2000 years ago have been found in bogs, covered by 10 feet of peat.

For use as a fuel peat is often dried and pressed into blocks.

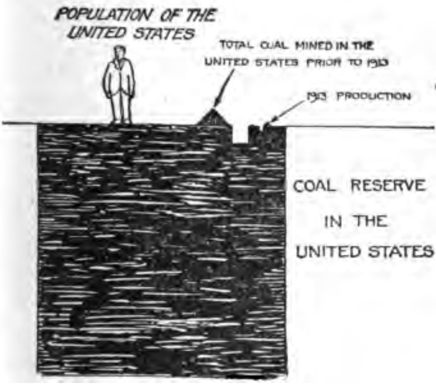


FIG. 83A.

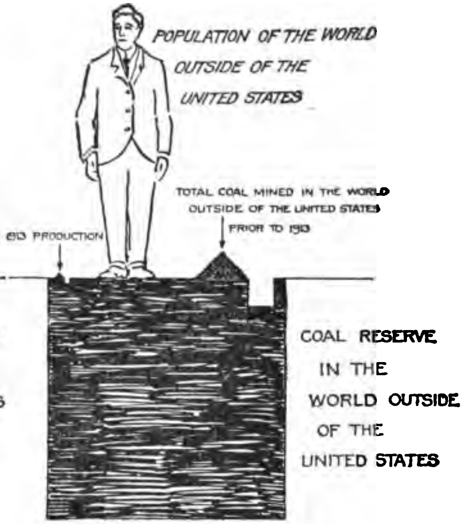


FIG. 83B.

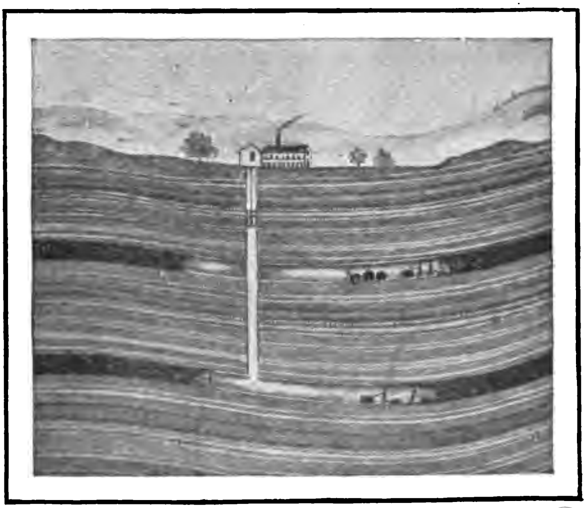


FIG. 83C.—Mining Coal.

Questions

1. Why is water gas more dangerous to use than coal gas or "city gas"?
2. How many tons of coal are required to heat your home?
3. Why should great care be taken to regulate the drafts of a coal fire?
4. Why does a blue flame appear over a coal fire when the stove door is opened?
5. Why is heat lost if water boils violently and steam escapes around the cover?

VENTILATION

Results of Burning.—Most fuel gases contain carbon, carbon monoxide, and hydrogen. We have learned that oxygen unites with substances to form oxides during the process of combustion. Carbon unites with oxygen to form carbon dioxide; carbon monoxide unites with oxygen to form carbon dioxide. Hydrogen unites with oxygen to form **hydrogen oxide** (water, H_2O).

Symbols are used to express these compounds. C stands for carbon, O for oxygen, and because two parts of oxygen unite with one part of carbon the formula for carbon dioxide is CO_2. Carbon monoxide is expressed by CO. More oxygen can unite with this compound; therefore, it can burn. When oxygen can no longer unite with the compound, that is, when it has all the oxygen it can hold, it can no longer oxidize, that is, can no longer burn.

Carbon Dioxide (CO_2).—Carbon dioxide will be seen to be the chief product of combustion. We have already learned that this gas is useful in extinguishing fire. It is also used for charging "soda water."

Large quantities of the gas are forced into pure water in tanks. These tanks are attached to the soda water fountain, and the carbonated water is drawn off into glasses, flavored with chocolate, vanilla, etc., and sold to the customers.

Sources of Carbon Dioxide (CO_2).—Every chimney is discharging large quantities of CO_2 to the atmosphere. The burning of gas, the burning of wood, and the exhaling of air by human beings and animals yield to the air quantities of carbon dioxide.

A single adult will exhale nearly 2 pounds of carbon dioxide every day, or about 22 cu. ft.

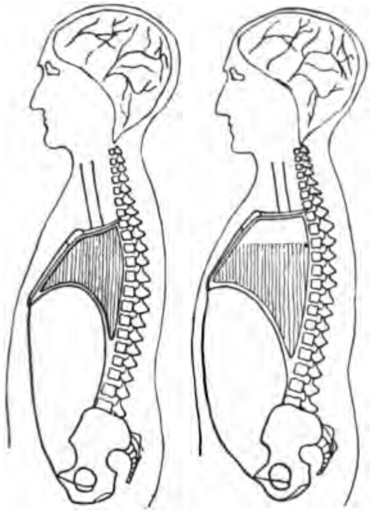


FIG. 84.

FIG. 85.

Amount of Air Breathed.—The amount of air in the average person's lungs is from 210 to 215 cubic inches. The **tidal air,** or the air in process of exhalation and inhalation, amounts to about 20 to 30 cu. in. An adult uses about 30 cubic inches of air at each breath. The average person breathes about twenty times per minute.

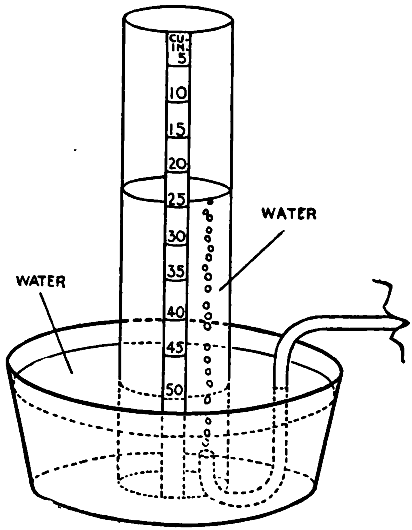


FIG. 86.

Fill a large bottle or cylindrical jar with water and invert it in a large pan of water. Place a rubber tube under the mouth of the jar, as shown in Fig. 86. Take the deepest breath possible. Place one end of the tube in the mouth and force as much air as possible from the lungs into the bottle. Determine from this the number of cubic inches of air forced into the

bottle. Such an instrument may be called a **spirometer**, an instrument for measuring lung capacity.

Upon a strip of paper pasted on the side of the bottle, a scale may be drawn so as to show the number of cu. in. of water forced out of the bottle.

A gallon contains 231 cu. in.

A cubic centimeter contains .061 cu. in.

Need of Ventilation.—All authorities agree on the necessity of ventiliation, to conserve the health, but not all agree as to the reason why air must be constantly changed. Some have believed that carbon dioxide makes the air "impure." This is not generally accepted to-day. Others say that the air becomes heated by the presence of people in a limited or confined space—they are forced to take shorter breaths, and the general activity of the body decreases. Another stated reason for ventilation is that noxious gases called anthrotoxins are exhaled which, if breathed in large quantities, have poisonous effects on people. All agree, however, that large quantities of fresh air are necessary to the right kind of activity for mind and body.

To maintain the proper degree of purity of the air in an occupied room, not less than about 2000 cu. ft. of fresh air per person per hour are required.

Children at different ages require different amounts of air. In the primary grades each child should get about 2000 cu. ft. of air per hour, and in the grammar grades from 2500 to 3000 cu. ft. of air. The children do not breathe all the air, but each child vitiates this amount and renders it unfit to breathe.

It is possible, as far as the amount of oxygen in exhaled air is concerned, that the air be reinhaled, since the lungs may and do contain a large percentage of CO_2, and pupils could get along on a smaller amount of air. But the rule should be definitely fixed in mind that fresh air is "Nature's Greatest Remedy" for keeping us well, and the nearer the percentage of CO_2 in the air of the room approaches to that out-of-doors, the nearer we are living as nature intended.

Different Amounts of Oxygen in the Air.—Normal air contains about 21 per cent oxygen. A lit candle goes out in air containing less than 17 per cent, but the percentage can be reduced temporarily to about 14 per cent without any apparent effect on the body. If the proportion is reduced to 12 per cent, the breathing becomes altered. At 10 per cent the color of the face of a person breathing it becomes of a leaden hue, the heart palpitates, bodily and mental activity become difficult. At 6

per cent consciousness is lost; and death takes place when the percentage of oxygen in the air is reduced to 3 or 4 per cent.

	Per Cent of Oxygen.	Per Cent of Nitrogen and Rare Gases.	Per Cent of Carbon Dioxide.
Pure air	21	79	0.03
Expired air	16	79.6	4.39

The air upon leaving the lungs contains more than 100 times as much carbon dioxide as the air that enters.

Laws Regarding Ventilation.—The ideal room should have about 600 cu. ft. of air space for each person. Some States require that each classroom shall have 30 cu. ft. of air per minute for each pupil, by an approved ventilation system; that each pupil shall have 18 sq. ft. of floor space and at least 200 cu. ft. of air space, and that all classroom ceilings shall be not less than 12 feet from the floor.

What does the law require in your State? Teachers and students should demand that these conditions be met to safeguard their health. See that the law is lived up to. This is one way of being a good citizen.

Method of Ventilation.—Air should never be allowed to become stagnant in an occupied room. One of the best methods of ventilating a room is to flush it out several times each day by opening the windows. This should be done when the students are out of the room lest the cold draft with the sudden cooling have injurious effects on some of them.

Although the windows of the room should be opened during the day, this does not mean the room should be closed at other times so that no more fresh air is admitted. There should be a steady supply of fresh air, heated to the proper temperature, and having the correct amount of humidity.

A window board about 6 inches wide is another means of supplying fresh air. The board is arranged so as to fit the side of the window and the window-sill, and allow the air to enter from the open window behind the board. Fresh air will enter and be deflected upward toward the ceiling; it then gradually sinks and spreads throughout the room.

A piece of cloth stretched on a frame and fitted into the open window makes another type of ventilator which is quite practical and inexpensive.

A wood or grate fire is an excellent ventilator.

A heating system which introduces warmed new air is far better than a heating system which depends on direct radiation.

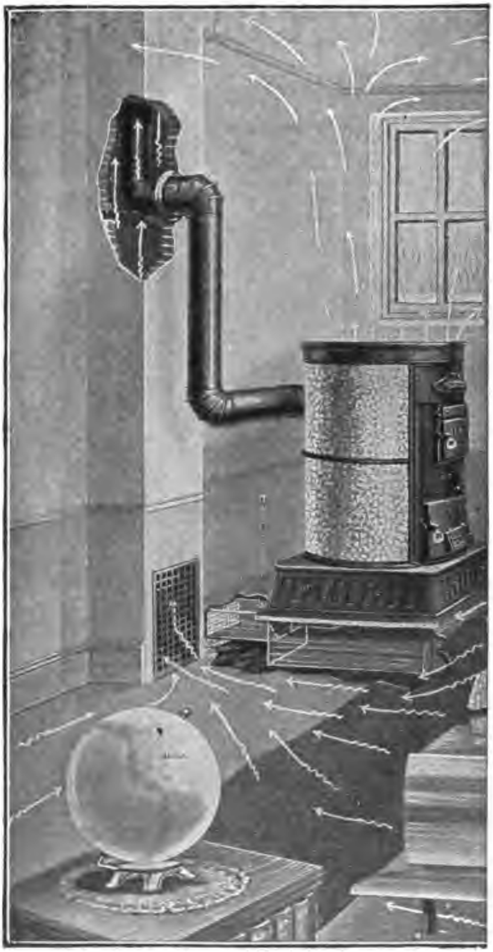


FIG. 87.—Air circulating about a jacketed stove. Fresh air is taken from outdoors.

Difficulty of Ventilation by Windows. — We have learned that fresh air from outside will flow into the room if the air inside is lighter than the air outside. This is usually the case during the winter months. It does happen in some climates that the outside temperature is the same or nearly the same as the inside temperature. Windows may be opened in the morning, producing a satisfactory amount of ventilation, but as the day gets warmer it is necessary to readjust the windows. One could hardly adjust the windows in the morning so as to expect sufficient

FIG. 88.—Board arranged in window.

fresh air to enter later in the day. The greater the difference in pressure between the outside and the inside of a building the less open the windows need to be.

Passage of Air through the Substance of Walls.—A small amount of air passes through the materials from which ordinary walls are made. More air passes through when the difference in pressure is great between the outside and inside of the house.

From 30 to 80 cu. ft. of air per sq. ft. per hour will pass through ordinary flooring for a difference in pressure of 1 pound per sq. ft. The amount of air which will pass through an ordinary brick wall for the same pressure and time will be about 48 cu. ft.

Carbon Dioxide not Injurious.—It has been definitely proved that carbon dioxide, as such, in the air is not injurious. People have worked for many years in mineral water factories or in breweries, breathing air which contains a relatively large proportion of carbon dioxide, without suffering ill effects. Carbon dioxide within certain very wide limits, up to 300 parts in 10,000 parts of air, appears to make very little difference.

The reason for this is that the presence of carbon dioxide in the blood excites the breathing centers, and automatically causes the breathing to be deeper and stronger, resulting in the quantity of carbon dioxide in the blood remaining constant.

The headaches and disagreeable feelings produced by breathing air in crowded rooms are due to the overheating, to the moisture of the air, and to the disagreeable odors, and not to the carbon dioxide.

Effects of Carbon Dioxide on the Body.—Although carbon dioxide, as such, is not considered dangerous in the air, carbon dioxide exhaled from the lungs with other substances seems, according to some investigators, to produce some ill effects on the body. Certain amounts cause drowsiness and mental dullness. Long exposure to such an atmosphere causes paleness. But this is because of decrease to below the proportion of oxygen necessary to maintain life, and to the vitiating of the atmosphere.

The "choke damp" found in mines is carbon dioxide. Often large quantities collect in wells. Before cleaning a well, lanterns are usually lowered into the well to test for its presence.

Tests to Determine Conditions of the Air.—Air can ordinarily be tested, for its fitness to breathe, by the sense of smell. However, the

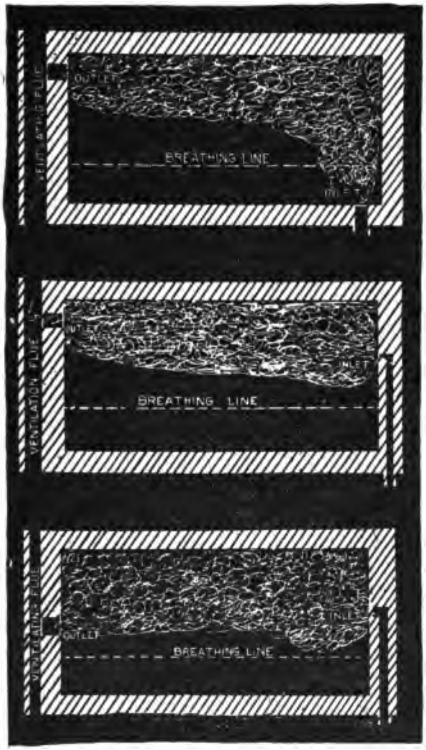


FIG. 89*a*

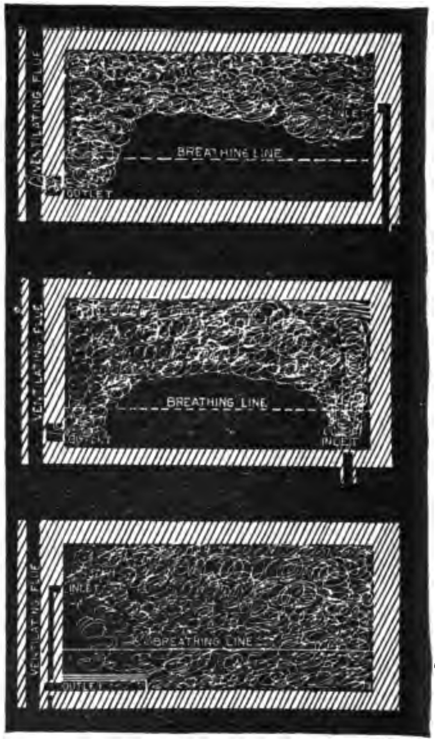


FIG 89*b*.

What is the effect on the ventilation of a room: 1. If the air enters at the floor and passes out on the opposite side at the top? 2. If the air enters on one side of the room near the top and passes out on the opposite side near the top? 3. If the air enters about half way from the ceiling on one side and leaves the room on the opposite side at about the same distance from the top. 4. If the air enters from the side wall a few feet from the ceiling and leaves on the opposite side at the bottom? 5. If the air enters from the floor on one side of the room and passes out on the opposite side of the room near the floor? 6. If the air enters and leaves on the same side of the room? 7. For good ventilation, what is the best way for air to enter and leave a room?

sense of smell is fatigued very rapidly, so that some one fresh from out-doors can make a more reliable test.

Thus, while the teacher and pupils, or members of the household might be unable to tell when the air was impure and unfit to breathe, anyone coming from out-of-doors would detect the odors of organic matter from the occupants' lungs and skins.

Experiment to Show the Best Method of Ventilation.—If you observe the duct for incoming air and the one for outgoing air you will see that they are on the same side of the room, one at the top and one at the bottom.

Build a small box to represent a room, as shown in Fig. 90. Place a piece of glass in front of the box, and bore four holes on each side to represent the ducts for incoming air and outgoing air, or the windows of a room.

1. Place two candles as in the diagram. Light the candles, after stopping the holes with a cork stopper. The candles will soon go out. Why?

2. Relight the candles and remove one stopper from each side at the top, *A* and *C*. The candles will burn for a short time, and then go out. Why?

3. Remove the two stoppers at the bottom *B* and *D*, with the other holes closed. The candles will go out after a short time. Why?

4. Remove the stopper at *A* on one side and at *D* on the other side. Watch the candles. Tell which candle is getting a better supply of air.

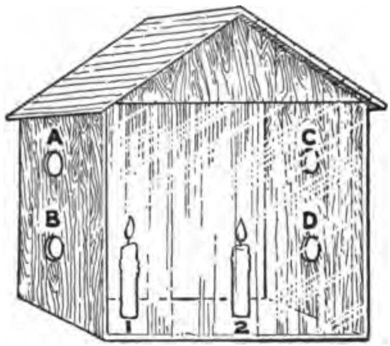


FIG. 90.

5. Open one hole at *A* and one at *B*, on the same side of the box. The candles will burn until used up, which shows that the best ventilation is obtained by having the openings at the top and bottom on the same side of the room.

Disease and Fresh Air.—Fresh air cures many diseases, especially consumption. If fresh air will cure disease, it will **prevent disease.**

Much of the disease and ill health now-a-days results from our crowded, overheated houses, and poorly ventilated schoolrooms. The open-air school is a step toward good health and prevention of disease. Sleeping with windows wide open, assuring plenty of fresh air, helps to make us healthy. Live and sleep out-of-doors as much as possible.

Even damp foggy air out-of-doors is far more healthful than air in the house. "Outdoor night air is better than indoor night air."

Deep Breathing.—" One hundred deep breaths a day " is an old recipe for avoiding tuberculosis. Ventilate the lungs every day by pressing the finger on the side of the nose so as to close one nostril, breathing in through the other nostril, and then out of the first. Reverse the process for every other breath. Singing causes deep breathing, and is a good way of getting fresh air into the lungs.

Air Vitiated by Lights.—Years ago candles were about the only means of illumination. The replacing of candles by gas and electricity made lighting more convenient, as well as more hygienic. In rooms where candles are used, the air is vitiated rapidly.

Every candle vitiates as much air as twelve people. A Welsbach gas light uses as much oxygen as three people. Electric lights do not vitiate the air.

Questions

1. What is foul air?
2. How does it affect life?
3. Why should people sleep with windows open?
4. What do miners call carbon dioxide?
5. What are the effects of breathing small quantities and large quantities of carbon dioxide?
6. What are some of the fallacies regarding ventilation?
7. What system of ventilation has your school?
8. What is necessary for proper ventilation of public buildings?
9. How may drafts be avoided in ventilating a room?
10. Why does sleeping out-of-doors benefit a person?
11. Why do some people consider night air unhealthful?
12. What kinds of lights do you use in your home?
13. How does one know when the air in a room is bad?
14. What is the best way of airing out a room?
15. In what position must the "inlet" and "outlet" of a ventilating system be placed to get the proper kind of ventilation?
16. Draw a diagram of the ventilating system of your school. (Special report.)
17. Test your lungs with the exhaling bottle for the amount of air you breathe out (described on page 107).

18. Count the number of times you breathe each minute.

19. Find the size of your schoolroom (3 dimensions).

20. How many cu. ft. of air space are allowed for each pupil?

21. How many cu. ft. of air space are allowed in your living room for each person (count in the lights)? In your sleeping room?

22. How often must the air be changed in your schoolroom? In your living room? In your sleeping room?

CARBON CYCLE

Digestion.—Foods contain: carbon and hydrogen in the form of **carbohydrates** (sugars and starches); **fats,** (butter, oils, fats of meat); **proteids** (white of eggs, lean meat, gluten of wheat). Most of our foods do not dissolve in water, or in the juices of the alimentary canal. The food eaten, such as butter, eggs, meat, bread, etc., must be changed to a substance which will dissolve and pass through the walls of the stomach and intestines into the blood. Digestion is the process of changing a food from a material which **cannot be dissolved** to a food which **can be dissolved** (from non-soluble to soluble.)

The principal fuel and source of energy in the body is sugar. No one eats in the form of sugar as such, anything like the required amount of this fuel. Each person would have to eat from a pound and a half to two pounds of sugar if the required amount were to be eaten **as sugar.**

It is the starch which we eat that furnishes the constituents for sugar, but this starch must be changed into sugar, since starch will not dissolve and pass into the blood. Our bread, crackers, cakes, cereals, potatoes, rice, corn, wheat, etc., contain large amounts of starch, and this has to be changed into sugar by the process known as **hydration**—Nature's method of adding water to the starch, thus changing it into sugar.

This process of digestion begins in the mouth. In the saliva there is a substance called ptyalin (tī-a-lin) which attacks the starch, and begins to change it into malt sugar. The food then passes to the stomach and is changed from malt sugar to grape sugar (so called because it was first found in grapes) or glucose. This process of digestion continues from the mouth all the way down the alimentary canal through the small intestines.

The grape sugar or glucose dissolves readily, and passes into the blood, where the hydrogen and the carbon oxidize, producing heat and energy. This process of oxidation is sometimes called *wet burning*.

How the Body Supplies Oxygen for the Burning of Food.—The blood gets its oxygen from the atmosphere through the process of **respiration.** The lungs are composed of a mass of air passages and air sacs (about 725,000,000). Because of the great number of blood vessels in the lungs, as much blood can go and does go to the lungs as goes to the remainder of the body at any one time. The walls of the lungs' air sacs are very thin. The oxygen passes through the walls of the sacs and enters the blood.

In the blood, red corpuscles containing a substance called **hemoglobin** receive the oxygen and act as the carriers of it. The hemoglobin unites with the oxygen, or in other words, takes a load of oxygen away from the lungs and delivers it to the cells of the body. When the stomach receives food a great many red corpuscles go to the vicinity of the stomach and intestines where the food when digested is entering the blood. The oxygen oxidizes the food, heat and energy being given off in the process. A part of the proteid food is used to build up the cells of the body; the rest is oxidized or burned up, forming carbon dioxide, water, and uric acid. The carbohydrates and fats, when oxidized, form carbon dioxide and water.

All of our foods, upon burning, give us heat and energy, which are required to maintain the body temperature and provide the strength to do our work.

Animals that Store away Food.—Animals that hibernate are able to do so by storing fat in the body and using it during the winter sleep. Camels store fat in the humps on their backs that they may be able to travel for days in the desert without food.

The Removal of Carbon Dioxide from the Body.—All the carbon dioxide produced by the burning of food in the body must be removed.

The carbon dioxide is dissolved by the **plasma**, the chief element of the blood, composed mainly of water. The function of the plasma is to carry waste. The hemoglobin of the red corpuscles also assists the blood plasma in disposing of the carbon dioxide. Its chief function, however, is to carry oxygen when the blood has circulated through the body and is dark red. This blood, now containing much carbon dioxide, passes through the arteries to the lungs where the carbon dioxide is given off into the air sacs in exchange for oxygen and expelled from the lungs into the air. The red corpuscles, after this exchange, are a bright red. When the blood is light red the substance in the red corpuscles is known as *oxyhemoglobin*, and when the blood is dark red the substance in the red corpuscles is known as *hemoglobin*, since it has lost its oxygen.

Disposal of Carbon Dioxide in the Atmosphere.—Countless numbers of human beings, animals and fires are constantly giving off carbon dioxide to the air.

The carbon dioxide of the atmosphere diffuses into the leaves and stems of plants. In the leaves there is a green coloring matter called **chlorophyll.** This chlorophyll absorbs certain light rays, and the energy obtained is used by the plants in uniting

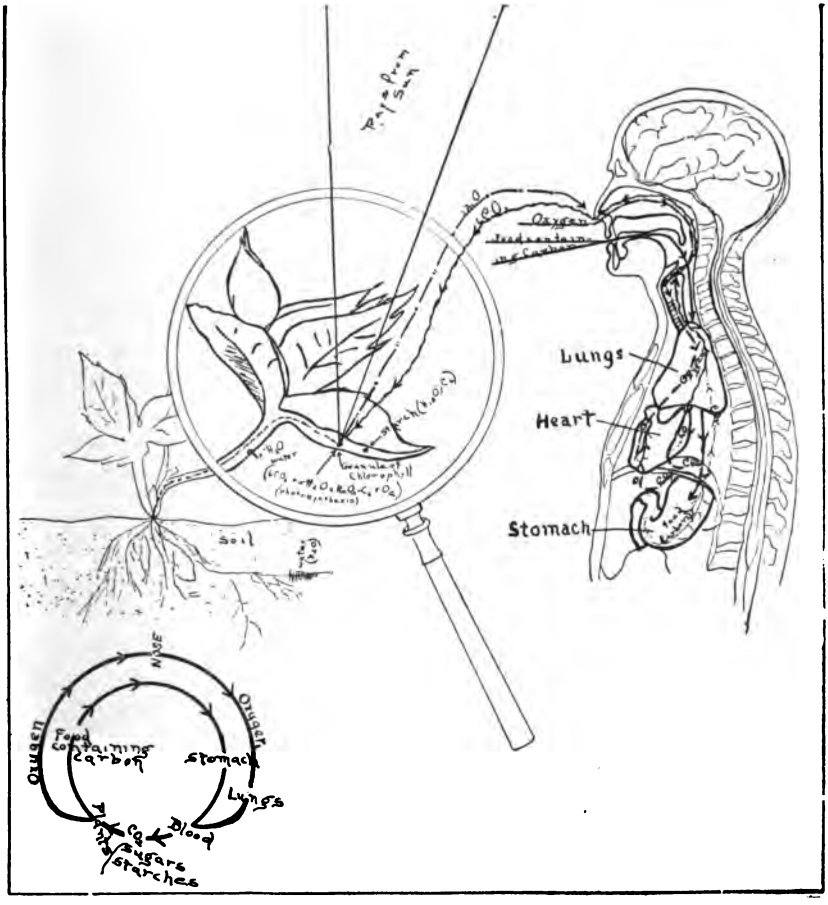


Fig. 91.—The Carbon Cyelc. Why is it necessary to eat food containing carbon? Why is oxygen necessary. What is given off by expiration? Why must plants have CO_2? What does the plant take from the soil? What becomes of the oxygen which plants give off to the air? What is meant by the carbon cycle?

the carbon dioxide from the air with water which comes up from their roots to form starch. Hence, the excess carbon dioxide of the atmosphere is used up by plants in forming starch.

How Starch is Manufactured.—All starch is composed of carbon, hydrogen and oxygen. Starch is usually composed of:

Six parts carbon (C_6),
Ten parts hydrogen (H_{10}),
Five parts oxygen (O_5).

Carbon dioxide and water, as we have seen, when reacting on each other in the plants, produce starch and oxygen. This oxygen is thrown off by the plant into the atmosphere.

Digestion in Plants.—In plants the starch is changed into sugar by a process of digestion, similar to that by which in the human body, starch is changed into sugar. After the starch has been digested, that is, changed into sugar, it is dissolved and distributed throughout all the growing parts of the plants.

Nature has thus provided that plant life should help animal life, and that animal life should help plant life. An atom of carbon passes from a human being or animal to a plant, and from a plant back to the human being or animal in the form of food. Thus the carbon cycle is complete.

Questions

1. What foods have you eaten to-day which contain (1) proteids, (2) fats, (3) carbohydrates?
2. Why should we chew our food well before swallowing?
3. Why do the Eskimos eat a great deal of fatty food?
4. Why is it necessary to remove the carbon dioxide from the body?
5. How do the winds assist us in keeping the air pure in winter?

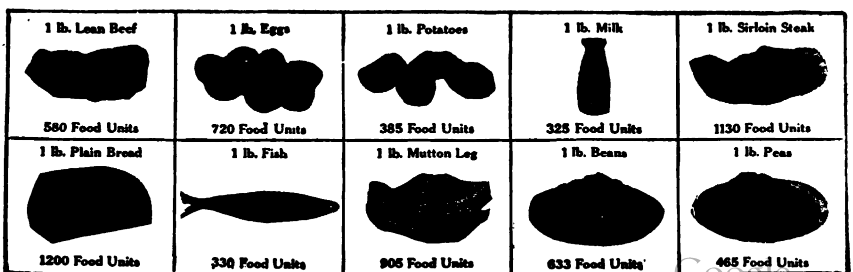
CHAPTER VII

FOOD AND MEDICINE

QUANTITY OF FOOD

Measurement of Food.—The body may be likened to a blacksmith's forge; the lungs the bellows, the food the coal. The lungs furnish the blood with air which burns up the fuel that we digest. The value of a food depends upon the amount of heat energy and repairing ability which, when the air-replenished blood acts upon it, are produced for the body's uses. This is measured in **Calories.** A Calory here means the amount of heat required to raise 1 kilogram (1000 grams of water) 1° C. or about 1 pound of water 4° F. This Calory is written with a capital C, thus distinguishing it from the calory written with a small c (the amount of heat required to raise one gram of water 1° C.).

The Calories of Foods Vary.—Not all foods have the same number of Calories per pound. Some foods are very rich in food value, while others contain a small number of Calories; for example, a pound of raisins at 12 cents has as much food value in Calories as 3½ pounds of lobster for $2.00. A pound of cornmeal flour has the same food value in Calories as 1¼ pounds of sirloin steak or 15 eggs. One would have to eat $9.00 worth of lettuce and tomato salad to furnish a day's requirement of Calories; while 30 cents worth of butter or 10 cents worth of sugar would give the same number of Calories. One should, nevertheless, eat freely of lettuce and other salad greens because of the vitamines (see pages 127 and 128).



Amount of Calories Required per Day.—Not all people require the same number of Calories of food. People who do heavy work require a greater number of Calories than those who do light work, since a greater amount of the body tissues, having been used up, must be rebuilt, and a greater amount of energy must be obtained.

Food and Weight.—Often the weight of a person may be regulated by the type and kinds of food he eats, except in the earlier years of life. Overweight is a more unfavorable condition in its influence on longevity than underweight.

Insurance companies have found that people who are slightly over weight before the age of 35 and slightly underweight after that age have a lower mortality than people who are underweight before 35 and overweight after that age.

If a person belongs to a family with a tendency to overweight, that person should early begin to form habits that will counteract this tendency.

The following table will show the relation between overweight and the death rate for men at different ages.

MEN—OVER AVERAGE WEIGHTS

Experience of 43 American Companies—1885–1908.
Number of Policyholders, 186,579

Ages at Entry.	Overweight 5 to 10 Pounds.		Overweight 15 to 20 Pounds.		Overweight 25 to 45 Pounds.		Overweight 50 to 80 Pounds.	
	Death Rate Below Standard.	Death Rate Above Standard.	Death Rate Below Standard.	Death Rate Above Standard.	Death Rate Below Standard.	Death Rate Above Standard.	Death Rate Below Standard.	Death Rate Above Standard.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
20–24	4	.....	4	.....	.....	1	.....	3
25–29	7	.....	10	.....	.....	12	.....	17
30–34	1	.....	14	.....	.....	19	.....	34
35–39	0	.....	.....	1	.....	31	.....	55
40–44	6	.....	.....	10	.....	40	.....	75
45–49	.....	3	.....	9	.....	31	.....	51
50–56	.....	2	.....	21	.....	24	.....	49
57–62	.....	2	.....	25	.....	12	.....	38

The heaviest mortality (75 per cent above the standard) is found among those aged 40 to 44 who are 50 to 80 pounds overweight.

As fat cells do no work, the number of working cells in fat people is relatively less in proportion to the weight than in thin people. Also there is less body surface exposed in proportion to the body weight, and proportionately less heat lost. Fat people are less active; therefore they do not need so much fuel. If they do consume as much food as thin people, the extra Calories are not burned up but are stored as fat.

Food to be Avoided by Overweights.—Sugar, fats, milk as a beverage, salmon, herring, mackerel, sardines, crabs, lobsters, pork, goose, fat meat, nuts, butter, creams, olive oil, pastry and sweets, water at meals—all these should be avoided by people who are overweight. Drugs or alcohol should never be used for reducing. The simplest way of reducing weight is to eat the right kind of food and take plenty of exercise.

Diet for Underweights.—Thin people lose heat more readily than stout people, as proportionately more active cells are on the surface and exposed. They require an abundant supply of food which will produce energy, such as fat, olive oil, and sugar used in other foods. Potatoes, bread, cereals, and starchy vegetables which are well masticated produce fat. Eggnogs are especially favorable as a food. After the age of 35 one need not be concerned regarding underweight unless there is evidence of ill health.

Diet in Hot Weather.—The amount of food eaten in hot weather should be decreased because less food is required to maintain the heat of the body. Fatty foods and all other foods which produce large quantities of heat should be eaten sparingly. These foods are far more valuable during cold weather. Ice cream, which is often considered cooling, is really a great heat-producing food, since it contains large quantities of fatty substances.

Food and Work.—People who do heavy work should not eat heavy meals while tired, as a person who eats heartily while in a tired condition is likely to be troubled with indigestion.

Brain workers do not require a special type of food, as is sometimes believed; they should take plenty of exercise, so as to keep the circulation of the blood in healthy action and thereby facilitate the normal activity of all the bodily functions, including the assimilation of the food, many of which functions are apt to lag when a sedentary person neglects to take regular exercise.

Perfect Food.—A perfect diet for a stout or sedentary person would not be a perfect diet for an emaciated or active person. A worker out of doors requires a different diet from that needed by a worker indoors.

A perfect food should

(1) Be readily absorbed or digested without imposing undue strain upon the digestive system;

(2) Be assimilable without waste;

(3) Contain the necessary amount of cellulose to be porous so as not to pack in the stomach and intestines.

(4) Contain proteins, fats, carbohydrates, vitamines and water in the exact proportions which would best serve the body's requirements.

Metabolism.—The process by which cells are nourished through the assimilation of food, while other cells are broken down to produce energy and heat, is called **metabolism.** Even if for a time we do not take nourishment enough, metabolism continues, thus using up the cells faster than they are built up. It is necessary that the process of metabolism be well balanced to keep the body in good condition.

Questions

1. What should a person know regarding a food besides its cost?
2. Is an expensive food more nourishing than a cheap food?
3. Name some foods which are cheap, but as nourishing as expensive foods.
4. Make a list of the foods you have eaten for a meal. List those that were expensive and those that were inexpensive.
5. What foods must one overweight regard as unwise to eat?
6. Are you underweight or overweight?
7. What foods are essential for underweights?
8. What other methods for reducing weight are advisable for overweights?
9. Why is it necessary to change the diet for hot weather?
10. Why is ice cream a great heat-producing food?
11. What would be a perfect food?
12. What kind of diet is a perfect diet for you?
13. Why is it necessary to eat a sufficient amount of food?

FOOD COMPOSITION

Food in General.—Foods may be classified according to their richness in:

1. Protein, which builds up the tissues of the body.
2. Fat, which stores up fat in the body and produces heat.
3. Carbohydrates, which change into fat and produce energy.
4. Vitamines, the active, minute, crystalline substances which are the vital forces in food.
5. Mineral matter, which supplies the body with the necessary minerals for good health.

The per cent of protein eaten should be about 10 per cent, of fat 30 per cent, and of carbohydrates 60 per cent.

Protein.—Foods should be so selected as to give the correct proportion (about 10%) of protein. Protein must be regarded as building material, and no more should be eaten than is required to repair the tissues which have been worn out by the activity of the day; 2½ ounces of protein a day is sufficient. If an excess of protein is eaten, waste matter, such as uric acid, and other poisonous substances, is formed. Such foods as meat and eggs are very high in protein values. Cheap sources of proteins are beans, peanuts, skim milk and cheese. Most foods contain protein. There are a few exceptions, such as butter, oleomargarine, oil, lard and cream, which consist of fat and water;* and sugar syrups and starch, which consist of carbohydrates and water.

Protein as Fuel for the Body.—The protein compounds are not only used for building and repairing tissue but, like the carbohydrates, are also burned directly in the body, thus rendering important service as fuel. The protein can be so changed in the body as to yield fats and carbohydrates, and such changes actually occur to some extent. In this and in other ways they supply the body with fuel.

A dog can live on lean meat. He can convert its material into muscle and its energy into heat and muscular power. Man can do the same; but so one-sided a diet would not be best for the dog, and it would be worse for man. The natural food for carnivorous animals like the dog supplies fats and some carbohydrates, and that for omnivorous animals like man furnishes fats and carbohydrates in liberal

* Small percentage of protein present, see chart p. 205.

amounts, along with protein. Herbivorous animals, like horses, cattle, and sheep, naturally require large proportions of carbohydrates.

Fat.—A proper proportion of fats in food is about 30 per cent. Fats contain no nitrogen, but have a great deal of carbon and hydrogen, which are easily oxidized, producing more energy than protein or carbohydrates.

Oils and fats have a laxative tendency, but they cannot be taken in too large quantities without impairing the appetite. Cheap sources of fats are oleomargarine and cotton-seed oil.

Carbohydrates.—Carbohydrate food, except milk, is chiefly produced from plants (proper proportion about 6%). Candies, sugars, starches, molasses, honey, etc., are some of the best examples of carbohydrates.

The chief sources of carbohydrates are sugar, starch, bread, potatoes, glucose, bananas, etc. These are great fat-producing as well as heat-producing foods.

DIGESTION

Digestion, as stated on page 115, is the process of changing a food into a substance that will dissolve and pass through the walls of the alimentary canal into the blood.

If sugar is placed in water it will dissolve: i.e., the sugar breaks up into particles which are distributed and held in suspension throughout the liquid. These particles are called molecules and they are understood to be the smallest part of a substance which can exist alone. Each molecule is made up of atoms. Molecules are of different sizes, some containing few atoms and others many thousand. When a substance does not dissolve the molecules do not separate, but cling together in one mass.

The *digestive tract* must change all foods which do not dissolve, to a substance which will dissolve so that the nourishment we take can get through the walls of the alimentary canal. Also, the resulting substance must be one in which the molecules are sufficiently small to permit their passage through the walls of the intestines and stomach.

Starch does not dissolve, but grape sugar does A molecule of starch is large, having 450 atoms in it. During the process of digestion a molecule of starch is split into ten molecules of malt sugar, but as these molecules cannot pass through the wall of the alimentary canal, they in turn are changed to molecules of grape sugar, each molecule of malt sugar being changed to two molecules of grape sugar. In other words, the one molecule of starch is changed into twenty small molecules of grape sugar which will dissolve and pass through the walls of the alimentary canal.

Protein molecules contain thousands of atoms which are changed into *peptones*.

Fats, after being emulsified (oil shaken with water, as an example) in the stomach, are carried to the intestines where a part changes to a fatty acid and is dissolved by

the bile. The remainder unites with the alkalis of the pancreatic juice and forms soap which will dissolve and pass through the walls of the intestines.

Why chew food well?

What kinds of foods begin to digest in the mouth?

What kinds of foods begin to digest in the stomach?

What kinds of foods digest in the intestines?

Why is it necessary to change protein to peptones?

Why is it necessary to change fats to soap?

Why is it necessary to change carbohydrates to grape sugar?

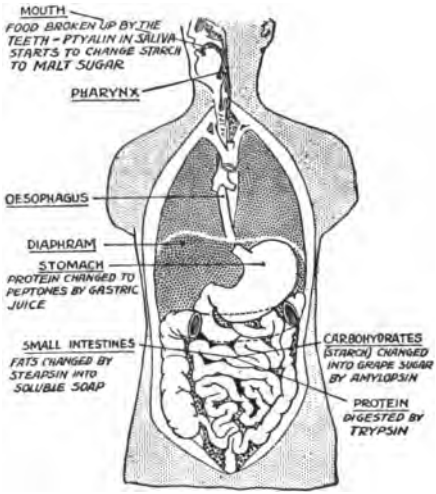


FIG. 92*a*.

COMMON FOODS CLASSIFIED *

	Poor in Fat.	Rich in Fat.	Very Rich in Fat.
Very high in Protein	White of eggs Codfish Lean beef Chicken Veal		
High in Protein	Shell-fish Skim milk Lentils Peas Beans	Most fish Most meats Most fowls Whole egg Cheese	
Moderate or Deficient in Protein	Most vegetables Bread Potatoes Fruits Sugar	Peanuts Milk Cream soups Most pies Doughnuts	Fat meats Yolk of eggs Most nuts Cream Butter

* "How We Live." Copyright, 1915, by Funk & Wagnalls.

Candies.—Candies eaten between meals are too seldom regarded as food; yet children may frequently be over-nourished by eating an excessive amount of sweets. Since candy may be considered a food, it should be free from adulterations, and, if colored, it should be colored with harmless dyes.

FIG. 92*b*.—An object lesson on cheap penny candy. This doll was prepared by the students of the State Normal School, Newark, N. J., from cheap unlabelled candy obtained at the penny candy-store near the school building. Buy candy which is labelled and is free from adulteration.

It may be well to mention chocolate candy in connection with carbohydrate food. Chocolate candy should not be given to children in any considerable quantity. A substance called *theobromine* in the chocolate is too strong a stimulant for their delicate nervous systems.

The use in candy of mineral substances, poisonous colors or flavors, or any injurious material is discouraged by reputable candy manufacturers.

Candies sweetened with saccharin, covered with shellac to keep moisture out, coated with talc, filled with earth or white clay in which glue has been used instead of gelatin, or red oxide of iron used to represent chocolate, and ethers used for flavoring, should be avoided. It is better to spend a few cents more for good candy than many dollars for doctors. Synthetic ethers for flavoring should not be tolerated, since true fruit flavoring may be procured.

Candy digests quickly; hence it is a food ready for use which can give nourishment and energy to the body quickly. However, one does not feel satisfied for any length of time from eating candy. It goes into the blood quickly but is soon used up. Foods which digest slowly are better for the system, because nourishment is supplied gradually, as required.

Candy in excess causes fermentation, with indigestion, and nausea. Sensible people eat candy at mealtime only, and in moderation.

Soda Fountains.—People should taboo soda fountains where saccharin is substituted for sugar, and ether for flavoring to produce strawberry, raspberry, pineapple, etc. Coal-tar dyes are sometimes used, to make the mixture look like a natural fruit product.

Places where benzoate of soda, salicylic acid, or calcium bisulphide are used for preserving food material or to conceal decay are dangerous to public health. Sometimes caffeine is sold in soft drinks or beverages for imparting exhilarating effects. To indulge in such refreshments is to invite the drink or the drug habit, or both.

Vitamines.—There are four kinds of vitamines known. They are considered as vital forces in foods, and they cure diseases of nutrition. Raw and uncooked foods, such as lettuce, celery, tomatoes, fruits, milk, and all foods which have not been heated above the body temperature, contain vitamines. In foods which have been cooked, many of the vitamines are destroyed or diminished in value. *They are exceedingly important to life.*

Many experiments made on pigeons and guinea pigs have shown that the health, and even the lives of the creatures depend upon the vitamines present.

Scurvy has long been known to be incident to a restricted diet, particularly a diet lacking in fresh vegetables, and meats. It frequently develops on shipboard when only bread foods and canned goods are used, also in times approaching famine.

Fresh vegetables and fruits and their juices, and especially lime and lemon juices, have been recognized as remedies for scurvy which bring about a rapid recovery.

It is now believed that the recovery is due to a vitamine, or to several vitamines in the fresh vegetables and lemon juice.

Vitamines which Tend to Cure Diseases of the Nerves.		Vitamines which Tend to Cure Scurvy.	
Relatively Rich.	Relatively Poor.	Relatively Rich.	Relatively Poor.
Brewer's yeast Egg yolk Ox heart Milk Beef and other fresh meat Fish Beans Peas Oats Barley Wheat Corn	Sterilized milk Sterilized meat Cabbage Turnips Carrots and other vegetables of this type Highly milled cereals Starch Pork	Fresh vegetables Fresh fruits Raw milk Raw meat	Dried vegetables Dried fruits Sterilized milk Canned meat Dried cereals Pork fat

If bread be the main article of diet, it should be made of flour containing the bran; if rice, it should be the unpolished, since the coarse part of the cereal contains more vitamines.

Beans, peas, and other legumes should be eaten once a week at the least. Canned legumes are to be avoided, for canned goods usually have fewer vitamines. Fresh vegetables or fruit should be used at least twice a week, preferably daily. Cereals (unhulled) should be included in all soups. When corn is the principal article of diet, the yellow meal,* that is, that made from the whole grain, should be used. Potatoes and fresh meat should be used at least once a week, preferably daily. The use of preserved foods is to be avoided if either fresh or hydrated are obtainable.

Mineral Matter.—Mineral matter is indispensable in one's regimen because it forms 5% to 6% of the body weight. Such foods as fruits, vegetables, nuts, eggs, and *baked-potato skins* contain much mineral matter. Mineral matter goes to the forming of bones, hair, teeth. It also aids in digestion and is found in the blood.

Foods Containing Minerals.—Beans, peas, and lentils are rich in potassium, phosphorus, calcium, magnesium, and contain traces of iron, sulphur, silica, chlorin and sodium.

* Also whole white meal.

The cereals also are liberally supplied with mineral matter. Oats are the richest, barley next and wheat third; rye, corn and rice follow in this order.

Among the vegetables, spinach has the greatest amount of mineral matter, followed by cabbage, horse radish, lettuce, carrots, radishes, onions, cauliflower, cucumbers and asparagus. The green vegetables (excepting potatoes) do not have much protein and starch.

Among the dried fruits, dried figs are richest in mineral matter. Then come figs, blueberries, followed by strawberries, prunes, cherries, apples, peaches, gooseberries, and grapes. Apples and strawberries have a large percentage of sodium. Strawberries, gooseberries and prunes contain large amounts of iron. The strawberry leads in this list, and is also rich in silica.

Nuts are rich in phosphorus, potassium, magnesium and calcium.

Eggs contain a large percentage of sodium, calcium, iron, phosphorus and chlorin.

Elements of the Human Body.—A man weighing 160 pounds possesses in his body about

45 lbs. carbon,	3½ oz. fluorine,
15 lbs. hydrogen,	3 oz. potassium,
90 lbs. oxygen,	2½ oz. sodium,
3½ lbs. calcium,	2 oz. magnesium,
1½ lbs. phosphorus	1½ oz. iron,
1½ lbs. chlorin,	1 oz. silica,
3½ oz. sulphur,	½ oz. manganese.

Sixty to seventy per cent of the human body is water (Hydrogen and Oxygen).

FOOD COMPOSITION AND USE IN THE BODY

Kind.	Composed of	Use.	Food Chiefly Found in
Proteids	Carbon Hydrogen Nitrogen Sulphur Phosphorus* Oxygen	Build tissues	White of eggs, curd of milk, lean meat, gluten of wheat, fish, chicken, etc.
Fats	Carbon Hydrogen Oxygen	For producing heat or for storing as fat	Butter, olive oil, oils of corn and wheat, cheese, fat meat, etc.

* Sometimes.

Carbohydrates	Carbon Hydrogen Oxygen	For producing heat or transformation into fats	Sugars, starches
Mineral Matter (Ash)	Sulphur Phosphorus Chlorine Sodium Potassium Calcium Magnesium Iron Silica	Aiding digestion, forming of bones, blood, hair, teeth	Potato skins, fruits, vegetables, nuts, eggs
Vitamines	Minute crystalline substances Destroyed or diminished by cooking except in acid fruit and acid vegetables	Vital force in foods Cure diseases of nutrition	Raw and uncooked foods such as lettuce, celery, tomatoes, fruits and milk. All food which has not been heated above body temperature

Questions

1. What are the essential materials in foods?
2. Why is eating protein food to excess unwise?
3. What foods are rich in protein? in carbohydrates? in fats?
4. Cheap sources of protein? carbohydrates? fats?
5. Why is a meat diet unhealthful.
6. Will a vegetable diet have the proper proportion of each food-element?
7. What is the best diet?
8. Why do Eskimos require fatty foods?
9. Why should candy be called a food?
10. Why should we eat some raw foods?
11. Why are fruits, nuts and eggs essential foods for the body?
12. What foods contain minerals?
13. How many Calories of protein, fat, or carbohydrates did you eat yesterday? What is the total? What amount of protein in excess did you eat, if any?

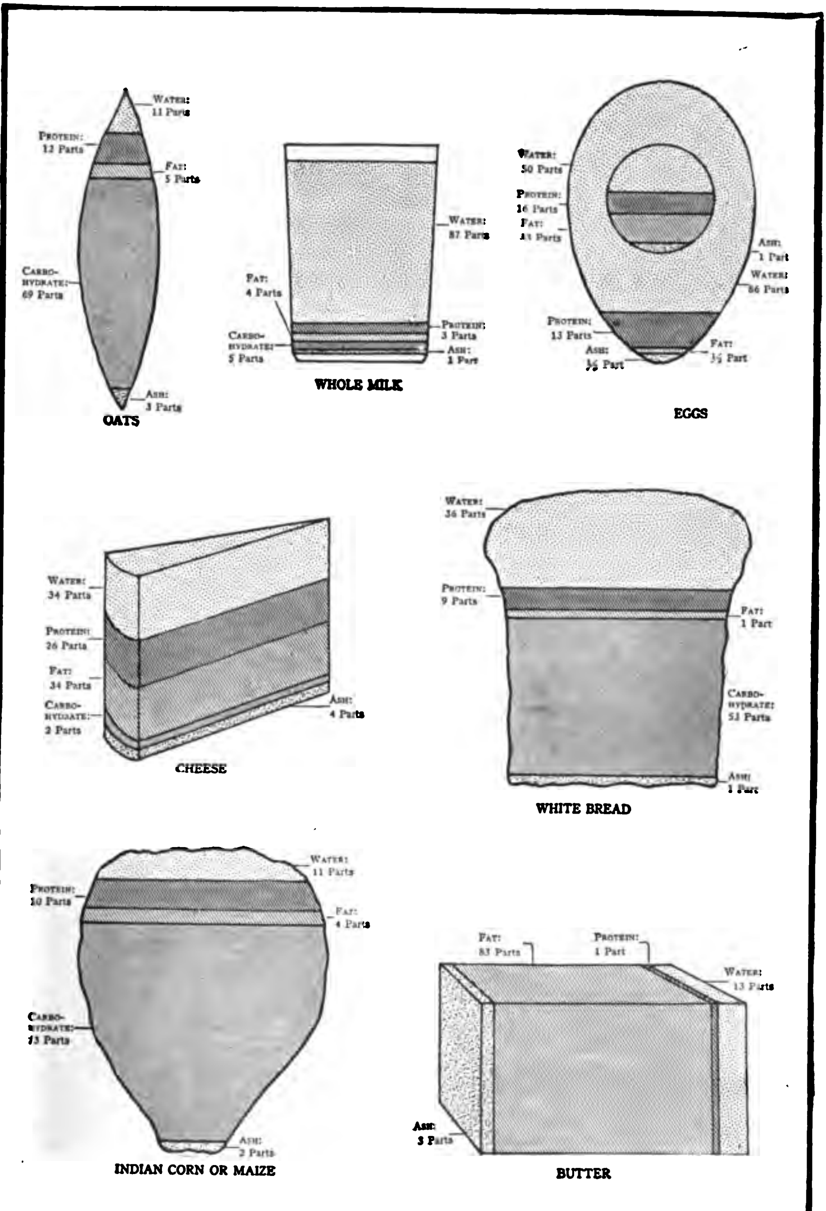
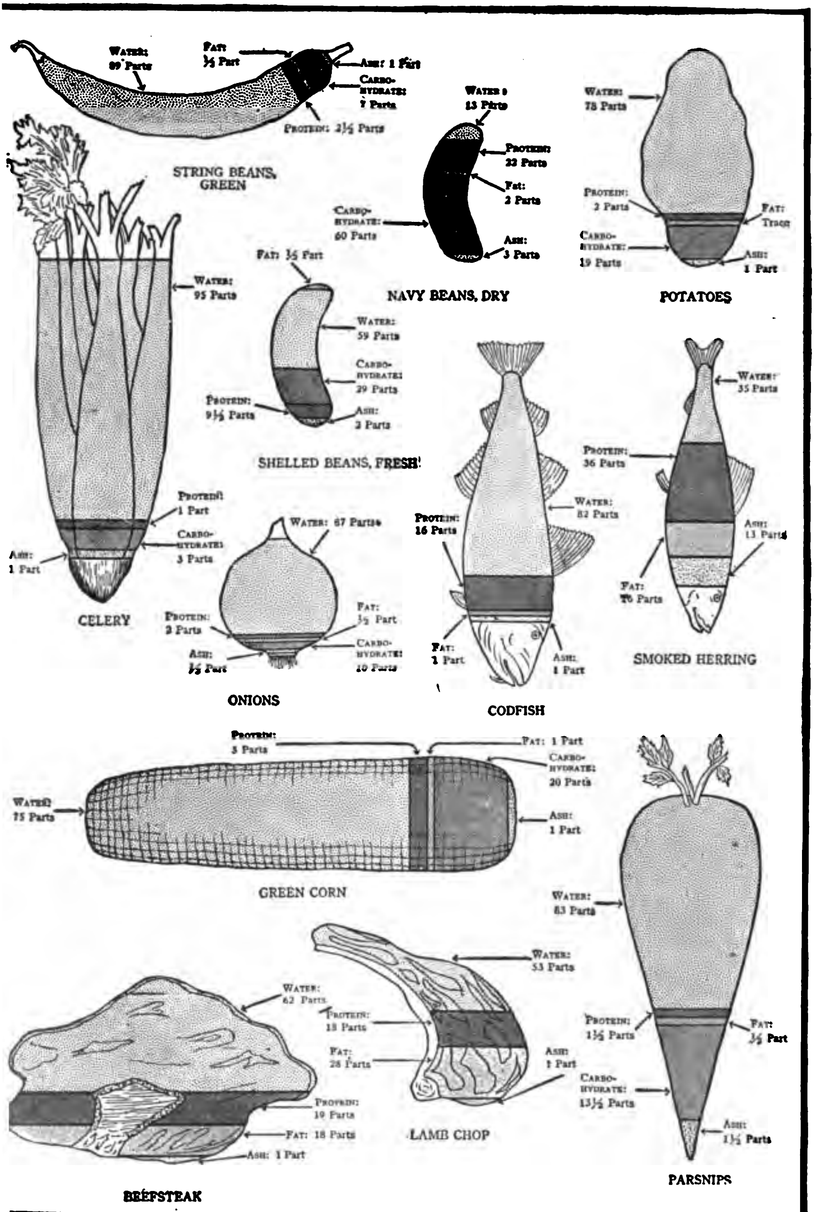


FIG. 93.—How do the above classes of food differ from meats and vegetables?



G. 94.—Which of these foods are richest in protein, carbohydrates, fats, mineral matter? Why should vegetables be eaten with meats?

14. Make out a diet for one day which will be cheap.

15. Make out a list of foods expensive for a day's supply.

16. How does a vegetarian obtain the necessary proportion of protein?

17. What is a well-balanced diet?

18. How does milk compare with eggs in food value?

19. How does a pound of nuts compare in food value with a pound of meat? Which is cheaper?

20. Compare rice, wheat, peas, and beans as to food value and cost. (Obtain cost from your grocer.)

21. What is the most valuable knowledge gained in this section?

COOKING OF FOOD

Why Foods are Cooked.—Most foods are better when cooked, because:

1. Thorough cooking sterilizes the food, killing molds, parasites, and bacteria.

2. Cooking renders many foods more palatable, and thus aids digestion because palatable food is more likely to be well chewed.

3. Starchy foods, such as vegetables, containing cellulose (a fibrous material), are more easily digested. Fruits such as bananas and green apples should be cooked because of the starch present. Pineapples and some kinds of pears and roots need cooking because of the cellulose in them. Cooking changes the starch to dextrine and glucose.

Nearly all the vegetables should be cooked, because of the presence of starch and woody fibres. Lettuce and tomatoes are among the exceptions. Celery contains little if any starch, although it is fibrous.

Over-cooking.—Over-cooked foods are apt to be bad for digestion. Cooking at high temperatures toughens some foods. Eggs are an example of this. Food should be cooked at a lower temperature than 212°, if possible. For this reason fireless cookers are far more efficient than ordinary stoves for cooking foods.

Steam cooking is often used because steam penetrates more deeply than water, dissolving the extractives of meat and other foods.

Enzymes, Proteids, and Digestion.—**Enzymes** are substances found in the glands of the body. The enzymes aid digestion by changing starch into sugars.

The digestion of carbohydrate foods starts in the mouth under the influence of an enzyme called **ptyalin.** Cold liquids and acids retard the action of the ptyalin in the digestion of carbohydrates. One should not drink water during the mastication of such foods.

Proteids do not digest in the mouth, but in the stomach and the intestines. Too much protein food will produce indigestion and bacterial decomposition in the intestines.

Digestion of Meat.—Meat should be carved across the grain in thin slices so as to cut the fibres into as many sections as possible. Long fibres digest slowly. The more fat in meat the more slowly it digests. Raw meat well chewed would digest more easily than cooked meat.

Chewing of Food.—Food must be chewed so as to break up the particles as much as possible, allowing the digestive fluids better contact. If the digestive fluids reach only the outside of relatively large morsels, much of the food may be a great waste because undigested.

Care of the Teeth.—The teeth are an important factor in digestion, and great care should be taken of them. Decav is caused by bacteria

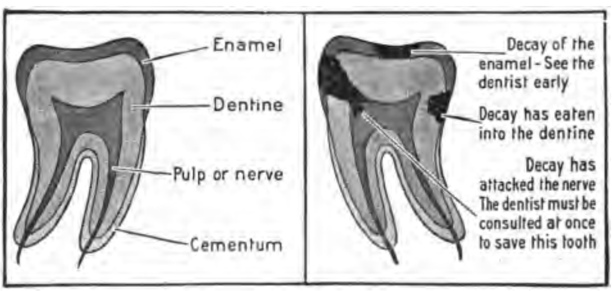


Fig. 95.—Why should the teeth be examined frequently? Why should the teeth be cleaned after every meal?

growing in the warm, moist food left between the teeth. If, after eating, the food is removed from the teeth with the aid of a brush and a good dentifrice, the danger from the bacteria is removed. One should avoid biting on threads, nuts, hard candy, or any other hard material, for it is liable to break the enamel; and decay will set in, wherever the dentine is exposed.

Tartar, a dark-colored substance which may collect on one's teeth, is supposed to be caused by bacteria. Tartar causes the gums to shrink, and exposes the necks of the teeth below the enamel. People should regularly visit the dentist, to have the tartar removed. Small cavities can be filled at a comparatively small cost. If one has not good teeth the stomach suffers.

Use of Fat in Cooking.—Fat encloses the food particles and hinders the digestive fluid from reaching the food. Fried foods, for this reason, are often indigestible. Butter, cream and olive oil are **emulsifiable** fats which do not interfere to any extent with digestion.

Frying with Fat.—Fat when frying is far above the temperature of boiling water. Fat for frying food should be very hot so as to form a crust on the outside of the food and prevent the fat from soaking in. Too much cold food placed in the fat at one time will cool the fat, which will soak into the food and surround the starch grains, preventing the digestive fluid from reaching easily the starch to change it into sugar.

If steak is placed in a cold frying pan with some fat, by the time that the pan becomes, hot enough for the frying each individual fiber of the meat acquires a layer of fat which prevents the food from digesting. Broiling, or cooking the steak in a hot frying pan, is the better way to prepare steak for eating.

Function of Warm Soup.—A warm soup at the beginning of a meal stimulates the appetite and also the secretions of the stomach.

Cooking of Vegetables.—Heat swells the starch granules, which burst, forcing apart the cellular structure in which the starch grains are located. This allows the digestive fluids to act on the starch. The cooking of vegetables accomplishes a similar effect.

Vegetables must be placed in hot water to *retain* their flavor, but if the flavor is to be *extracted*, as in the case of onions, the vegetables should be placed in cold water and slowly brought to boiling point.

Cooking of Meats.—Heat coagulates protein. If the juice is to be extracted, heat the meat slowly, keeping the temperature below 185° F., which will prevent coagulation. If the juice of meats is to be kept inside, the meat should be heated very quickly.

Sometimes meat is put into boiling water to coagulate the outside, then the temperature allowed to drop to about 185° F. This process of cooking, which is called **simmering,** makes the meat tender if cooked for a long time.

Cooking of Eggs.—Eggs should be placed in cold water and brought to a boil. The protein (albumen) of the egg coagulates at a temperature of 158° F., so that if the egg is put into hot water the white of the egg (albumen) coagulates, leaving uncooked the yolk within. An egg put into hot water *should not be allowed to boil.*

PERIODS OF DIGESTION

Length of Time Required for Digestion of Various Foods

	Hours.	Min.		Hours.	Min.
Rice	1	0	Mutton, boiled	3	0
Eggs, raw	1	0	Beef, roast	3	0
Apples	1	30	Bread, fresh	3	15
Trout, broiled	1	30	Carrots, boiled	3	15
Venison, broiled	1	35	Turnips, boiled	3	30
Sago, boiled	1	45	Potatoes, boiled	3	30
Milk, boiled	2	0	Butter	3	30
Bread, stale	2	0	Cheese	3	30
Milk, raw	2	15	Oysters, stewed	3	30
Turkey, boiled	2	25	Eggs, hard	3	30
Goose, roast	2	30	Pork, boiled	3	30
Lamb, broiled	2	30	Fowl, roast	4	0
Potatoes	2	30	Beef, fried	4	0
Beans, boiled	2	30	Cabbage	4	30
Parsnips, boiled	2	30	Wild fowl	4	30
Oysters, raw	2	55	Pork, roast	5	15
Eggs, boiled	3	0	Veal, roast	5	30

Questions

1. Why cook foods?
2. What is the effect of over-cooking food?
3. Why are fireless cookers efficient for cooking foods?
4. Why not drink cold water during the chewing of foods?
5. Why should food be well chewed?
6. Why is the proper carving of meat important to digestion?
7. What are the two essentials of a dentifrice?
8. What defect in the cooking of crullers renders them indigestible?
9. What is the value of warm soup before a meal?

10. Why should oatmeal be well cooked?

11. How should the cooking of onions and similar vegetables differ from that of beets?

12. How should beef be cooked to obtain beef extract?

13. What kinds of food would be bad to eat just before going to bed?

14. What foods digest easily? Slowly?

15. Why should one breakfast on food which digests quickly?

16. What is the advantage of foods which have different periods of digestion?

17. Why is the crust of bread sweet?

18. Why should invalids eat toast?

19. Why do thin pieces of potato become swollen when dropped into hot fat?

20. Why is the meat in a soup tasteless?

21. What part of this section do you consider of greatest value?

MILK

Source of Milk.—Milk is made from the blood of the cow by two large glands. The glands are soft, spongy organs, containing a fine network of ducts, and with secreting cells which prepare the milk from the blood. Milk contains all the food elements necessary for the growth and development of young animals.

Composition of Milk.—Milk is composed of water, fat, casein, albumen, milk sugar, and a few other substances in small quantities. The average cow's milk contains

Water 87.1 per cent		
Solids 12.9 per cent	Fat	3.9 per cent
	Casein	2.5 per cent
	Albumen	0.7 per cent
	Sugar	5.1 per cent
	Ash	0.7 per cent

The fat in milk is in the form of small globules. About 6000 of them placed side by side would measure an inch. The fat in milk varies from 2.2 per cent to 9.0 per cent. The United States standard is 3.25 per cent. What is the standard in your State?

Casein gives the milk the bluish white color and is the curd in sour milk. Much casein is manufactured from skim milk by chemical processes.

This casein, after treatment with certain chemicals, is often used for the manufacture of knife handles, billiard balls, piano keys, combs, backs of hair brushes, and countless other articles.

Project.—Look up the uses of casein, and processes for manufactering articles from it.

Mineral Matter in Milk.—Milk also contains calcium, iron, magnesium, potassium, sodium, sulphur and phosphorus. All these minerals are essential to the human body, and are usually spoken of as *solids not fat.* The average amount of solids not fat in milk should be about 8.2 per cent.

Adulterations of Milk.—Milk is adulterated by:

1. Addition of water.
2. Removal of cream.
3. Use of preservatives.

To tell whether the cream has been removed from the milk, and to determine the solids not fat, tests for the amount of fat have been established and are now generally enforced by Government.

The old practice of watering milk has largely disappeared, since the Babcock test so easily determines whether the grade of milk is good or poor.

Pasteurization.—If milk is heated for twenty minutes at a temperature between 140° and 180° most of the malign bacteria become inactive. Heating at this temperature does not destroy the taste of the milk. This process was originated by the famous French chemist, Pasteur.

Questions

1. Why is milk one of the essential foods?
2. Why should milk be well cared for?
3. What precautions should be taken in the handling of milk?
4. What happens when the milk in a bottle freezes?
5. Why should milk bottles full of milk never be left on a door step to freeze in the winter? (Suggestion—stray dog or cat.)

6. Why should a box with a cover be placed outside the house so that the milkman may place the milk in it?

7. Why is milk sometimes adulterated?

8. Why do cities and towns often require that milk be sterilized?

9. **Project.**—Find out the requirements of the Board of Health in your town or city regarding milk.

USES OF CARBON DIOXIDE IN COOKING

Use of Ammonium Carbonate.—Sometimes ammonium carbonate is mixed with flour in order to form a gas for raising dough during the process of baking. The ammonium carbonate changes into carbon dioxide, water, and ammonium gas.

Use of Baking Soda.—Another way of raising bread is to use sodium bicarbonate (baking soda) which, when heated, gives off carbon dioxide and water, but the product left in the bread is unwholesome.

Use of Hydrochloric Acid and Baking Soda.—We have learned that an acid and a carbonate produce carbon dioxide. This method of producing carbon dioxide has been used for raising bread. Hydrochloric acid and baking soda produce carbon dioxide and common salt, but bread raised by carbon dioxide made in this way has not been very satisfactory because of its flavor.

Baking Soda and Molasses.—Molasses contains some free acid which acts upon baking soda and produces carbon dioxide. Vinegar is sometimes added when the acid in the molasses is not sufficient. Gingerbread may be made by this process..

Sour Milk Bread.—Sour milk contains an acid known as lactic acid. When sour milk and baking soda are used to produce carbon dioxide for raising bread, sodium lactate, a harmless salt, is left in the bread. An excess of baking soda in this operation causes the bread to become yellow and unwholesome, since washing soda is formed in the product.

Baking Soda and Cream of Tartar.—When cream of tartar and soda are used for making bread, carbon dioxide is formed, and Rochelle salts is left in the bread. Much has been said about the unwholesomeness of this residue, but, although a loaf of bread will have more of this salt than a seidlitz powder, the amount of bread eaten at one meal is so small that the effect on the system may be disregarded.

Yeast in Making Bread.—The use of yeast in making bread light has been known from ancient times. It may have been learned by accident

"*Wild yeast*" is floating in the air everywhere. If dough is left exposed to the air some of the wild yeast is sure to fall into it.

In bread making, the dough is kept in a warm place for a time, during which the yeast acts upon the small amount of sugar which is found in all cereals. The housekeeper always places the dough in a place where the temperature will be such as to make the yeast plants active. They produce carbon dioxide and alcohol from the sugar, causing the bread to rise. The heat expands the gas after the bread has been put into the oven, and the carbon dioxide and alcohol escape by diffusion. Bread raised by the use of yeast contains no harmful ingredients such as are sometimes left by the use of baking powder. During the process of cooking the bacteria are killed.

Bread left too long to "rise," will sour, because the yeast plants change the alcohol into an acid.

Questions

1. Why is carbon dioxide an essential factor in bread making?
2. Why are places cut in the dough on top of a loaf of bread?
3. Why do some people prick the top of the bread with a fork?
4. Why is bread kneaded?
5. Why are there sometimes large holes in certain parts of the bread?
6. What causes sour bread?

FOOD PRESERVATION AND ADULTERATION

Reasons for Preserving Food.—Food may be preserved when, being in season, it is easy to obtain and, perhaps, low-priced, and used months afterwards when the season for such food has passed. Preserved food enables a varied diet which would not have been possible in the early history of man.

Methods of Preservation.—The *canning* of fruits and vegetables is one of the best means of preserving food, since bacteria, and the air (oxygen) which aids their processes, may be kept away from the food. The food must be cooked first at a temperature of or above 150° F.

Cold storage keeps food, since most forms of bacteria do not live, or are not very active, below 40° F.

Wrapping fruit *in paper* helps to preserve it, and hinders the spreading of decay from one fruit to another.

Keeping fruits and vegetables *dry* is an important aid in keeping them sound. One of the reasons why vegetables and fruit do not keep as well after being in cold storage is that the food is cold, and moisture condenses upon it, affording a place for bacteria to grow.

Chemicals are sometimes used to preserve food. If chemicals are used, they must be of a character that, while actually preserving the food, shall be harmless to the consumer. Sugar, salt, vinegar and spices preserve food; also, smoke from smoldering wood preserves food in a harmless way.

Other methods of preserving food are through the use of alum, borax, boracic acid, benzoic acid, and sulphites. But with foods preserved by these chemicals there is always the danger of excessive proportions having been used. *No one need use* food preserved with any of the above chemicals, for the law requires that the label on the case or bottle shall tell whether the food is preserved with any of them and, if so, which. *Using your eyes to read the labels* is one of the best safeguards when purchasing preserved foods. If a bottle of ketchup contains benzoic acid, or benzoate of soda, insist on a brand which does not contain a chemical.

It is true that the law permits the addition of chemicals to foods if not in sufficient quantity to be detrimental to health; but there are reasons for believing that the continual accumulation of poisons in the human body sooner or later prevents the human system from doing its best, and is the cause of the *rapid increase of organic diseases*. The *best way* is to *avoid* all foods preserved with such *chemicals*. *Eat food that you know to be wholesome.*

Eggs Preserved.—A 10 per cent solution of silicate of soda (water glass) is used extensively for preserving eggs. It forms a thin film over the egg, preventing bacteria from entering.

Questions

1. What is the best way to preserve foods?
2. Why should we avoid all food preserved with alum, boracic acid, benzoate of soda, etc.?
3. How does water glass preserve eggs?
4. Why should paper be wrapped about fruit?
5. What is the best way of preserving ketchup?

6. What is apt to be the condition of soda fountain goods preserved with benzoate of soda? ($\frac{1}{10}$ of 1 per cent.)

7. Why are bottles containing liquid often deceptive as to the amount of contents? (Refer to Fig. 96, below.)

FIG. 96.—Three Bottles of Extract (front and side views).

This shows the impossibility of correctly estimating the quantity of contents from apparent size of the container. The bottle which is apparently smallest holds the most, and vice versa.

8. Examine the labels on your ketchup bottle, can of peas and other canned foods.

9. Make an exhibit of all the different containers of foods and labels you are able to obtain.

Oleomargarine.—Oleomargarine is made by churning one or more vegetable oils with, in some brands, the "oleo oil" obtained from beef fat, or with the "neutral oil" obtained from lard. But much oleomargarine is now made containing no animal fat at all. Oleomargarine has as much food value as butter, and is slightly more digestible.

Renovated Butter.—Renovated butter is made from old and rancid butter. Air is blown through the material to remove the unpleasant odor. It is then liquefied and churned with milk to produce the butter.

Butter Test.—To distinguish between oleomargarine, renovated or process butter, and genuine butter, the "spoon" test may be used.

Heat in a tablespoon a piece of butter about the size of a cherry, stirring with a match. On boiling, genuine butter makes little noise, but produces much froth; renovated butter boils noisily with a small amount of foam, while oleomargarine boils with more or less sputtering, and produces no foam.

NOSTRUMS

Health.—Good food, plenty of pure air and an abundance of exercise produce healthy people. The kind of food we eat and the way we eat it govern our health to a large extent. Too many people are trying to doctor themselves with "patent medicines" which are not only useless but positively harmful. If one is suffering from any ailment, he should

go to a reliable physician. The doctor will be able to diagnose the case better than any "Patent Medicine" man (who may or may not have had medical practice).

Alcohol in Medicine.—Every year thousands of people have spent millions of dollars on patent medicines. Millions of gallons of alcohol and a large quantity of opiates and narcotics, ranging from powerful, dangerous heart depressants to strong stimulants, have been thus consumed each year.

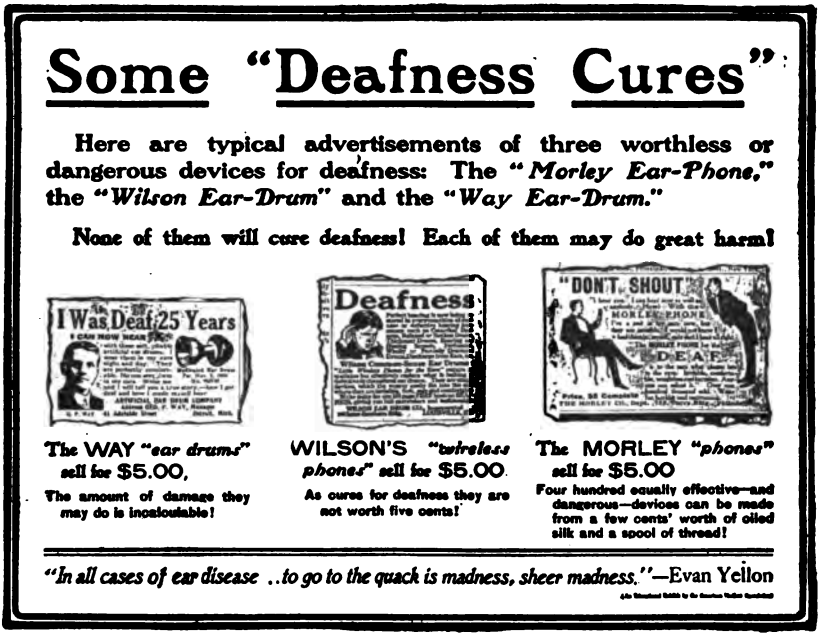


FIG. 97.

Composition of Some "Patent Medicines."—Some of the widely sold "patent medicines" have been found to contain dangerous or useless substances, such as burned sugar, and alcohol with a flavor added. Rochelle salts with olive oil has been sold as a stomach remedy. Dilute hydrochloric and sulphuric acids are used in many medicines which do not contain alcohol. These are sometimes called microbe killers, etc. Such medicines have been advertised to cure:

Asthma
Abscess-Anemia
Blood Poison
Bowel Troubles
Coughs—Colds
Consumption
Contagious Diseases
Cancer—Catarrh
Dysentery—Diarrhea
Dyspepsia—Dandruff
Eczema—Erysipelas
Fevers
Gallstones
Goiter
Gout
Hay Fever—Influenza
La Grippe
Malaria—Neuralgia
Meningitis
Piles—Quinsy
Rheumatism
Scrofula
Skin Diseases
Tuberculosis
Tumors—Ulcers
Throat Troubles—Bronchitis

FIG. 98.—The evolution of the Swamp Root label since the Pure Food Law passed. Why do you think the word "Cure" was changed to "Remedy"? Why do you think the statement "cures all" was changed to the mild statement "is recommended for"? The example is only one of many.

One medicine alone has been advertised as a "cure" or "remedy" for any and all of the diseases mentioned. Such words as "cure" have been removed from the label of a great many patent medicines and the word "remedy" substituted because they were fraudulent and *not* a cure for any disease, and because the Food and Drug Act prohibits the printing of fraudulent claims on the trade package or label. Sometimes a patent medicine has even the word "remedy" omitted, and the word "for" alone stands out to deceive the public.

Poisons.—Many deaths, as well as permanent injury to health, have occurred through the use of headache powders and pills which contain some drug, such as **phenacetin, acetanilid, morphine, opium, heroin, alcohol, chloral.** The best rule for those who wish to attain the highest physical and mental efficiency is to avoid all types of habit-forming drugs. One who forms the habit of taking these medicines may become so addicted to the use of them that the habit becomes a disease itself, dangerous, and almost impossible to break or cure—like the morphine or opium habit which has caused misery and death to innumerable addicts and their loved ones.

Questions

1. How do some patent medicines in respect to alcoholic contents compare with liquors?
2. Why should we avoid all medicines which do not state the contents of the bottles on the labels?
3. Why are medicines frauds which claim to "cure" or to "remedy" many ills?
4. Why are children apt to form the taste for alcohol and dangerous opiates if they are fed cough syrups and soothing syrups?
5. Why may people who regularly take headache powders form a "dope habit"?
6. Why should people who have incurable diseases avoid patent medicines?
7. What is the chief objection to buying patent medicines even if they contain no injurious material?
8. Why should people never buy a "patent medicine" for serious ailments?
9. What do you consider of greatest value in this section?

CHAPTER VIII

WATER

FACTS ABOUT WATER

Water.—One of the most abundant and widely distributed compounds on earth, water, being a solvent for many substances, is never found pure in nature. When pure, however, it is tasteless, colorless and odorless. There is water in the majority of things about us—the papers we use, the wood in our homes, the food we eat, the air we breathe. For example, eggs and potatoes are three-quarters water, solid rocks contain water, and even our own bodies are 65 per cent water.

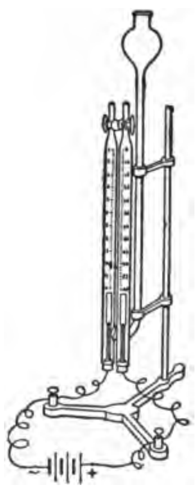


FIG. 99.

Composition of Water.—Water is a compound of two gases, hydrogen and oxygen. These gases are called **elements.** An element is a substance which can not be decomposed into simpler substances. Scientists have found that there are only about 83 different elements, but by combining them in different proportions various kinds of substances may be obtained. Thus by combining 2 parts of hydrogen with 1 part of oxygen, water is obtained.

Electrolysis.—There are several convenient processes by which water may be separated into its elements. One process, employing electricity, is called **electrolysis.**

Experiment in Electrolysis.—Water is poured into the bowl of the apparatus shown in the diagram until the two upright tubes are full of water. A little sulphuric acid is added, as the acid allows electricity to pass through the water. The wire from the platinum strip in the bottom of one tube is connected with the positive pole of a battery, the wire from the platinum strip

in the other tube is connected with the negative pole of the battery. When the current is turned on, bubbles will be seen to rise in both tubes; but the bubbles in the one will prove to be hydrogen, in the other tube the bubbles will be oxygen.

Specific Gravity.—A knowledge of the density or specific gravity of a liquid or a solid is often important to determine the purity or condition of materials. In the preparation of syrups, jellies and other food products, the determination of their specific gravity is a convenient way of knowing whether the evaporation or "boiling down" has been sufficient.

The specific gravity of milk is from 1.028 to 1.032. If the specific gravity is above this, the probability is that the fat content (cream) has been removed.

Gasoline has a specific gravity of 0.70 to 0.74. If the specific gravity of the gasoline is different from this we know that the gasoline is not of standard grade.

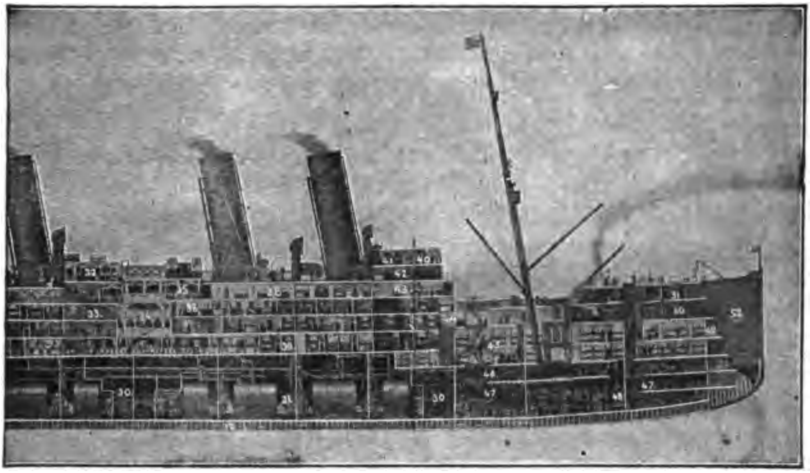
Electric storage batteries used in automobiles, etc., are tested as to their specific gravity to determine whether they are fully charged.

Meaning of Specific Gravity.—Specific gravity, of a *solid*, is the ratio of the weight of a substance to the weight of an equal volume of water; of a *gas*, the ratio to air. For example, zinc has a specific gravity of 7, which means that a cubic foot, cubic inch, or cubic centimeter of zinc is 7 times heavier than a cubic foot, cubic inch or cubic centimeter, respectively, of water. The weight of water is taken at 4° C. or about 39° F. Therefore, a good definition of specific gravity is: the ratio of the weight of any volume of a substance to the weight of an equal volume of water, if a solid; to air, if a gas.

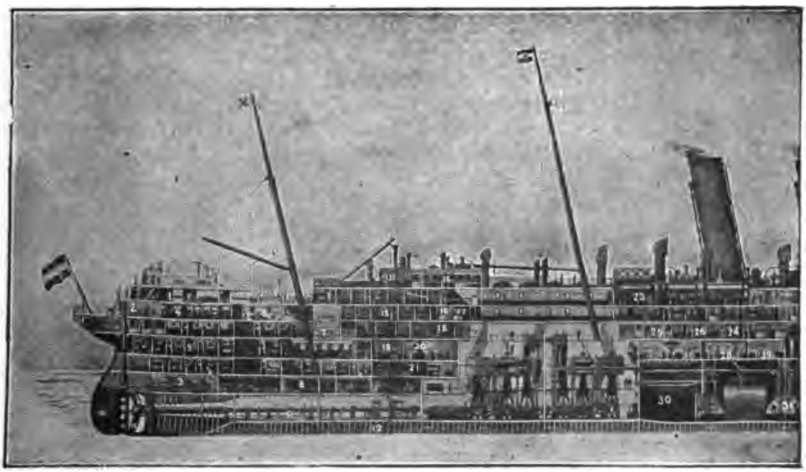
The specific gravity of the human body is 1.07, which means that a person is slightly heavier than water. A cu. ft. of water weighs 62.5 pounds. The human body then would weigh 66.8 pounds per cu. ft.

Floating and Sinking Bodies.—Place a wooden ball in a dish of water. It will sink to a certain depth and then float. Place in water a metal ball of the same size. It will sink. Weigh the metal ball out of water (using a spring scale). Weigh the metal ball in water. **The metal ball will be seen to have lost weight.** If possible, obtain a larger piece of metal, such as a small cannon ball; or a croquet ball loaded with metal will answer the purpose.

If a small ball is used, place the ball in a graduate. By the increase in height of the water in the graduate the amount of water displaced by the ball may be told. Weigh an equal amount of water. Weigh the ball in water. Compare the weight of the water with the loss of weight of the ball.



a



b

Fig. 100*a* and *b*.—This great ocean liner must sink in water until the water displaced equals the weight of the ship, the weight of the people, and all material on board.

If the croquet ball is used, fill a dish as full of water as it will hold. Place the ball in the dish, catching in a pan the water which overflows. Weigh the water thus known to have been displaced by the ball Compare the loss of weight of the ball with the weight of the water displaced.

A body floats in a liquid as soon as it has sunk to such a point that the weight of the liquid displaced by the body is equal to the weight of the body. If the body cannot displace enough water to equal its own weight it sinks, but it loses as much weight as the weight of the water it displaces.

A ship weighing 50,000 tons must push aside 50,000 tons of water. A cu. ft. of water weighs about $62\frac{1}{2}$ pounds. If a body displaces a cu. ft. of water, it loses $62\frac{1}{2}$ pounds of its weight. Because of these facts, architects and engineers are able to tell the weight of granite piers, steel columns, etc., without weighing them, since they know how many times heavier than water each cu. ft. of material is.

Submarines as Sinking and Floating Bodies.—An excellent illustration of how the submarine sinks and floats is the bobbing bottle.

Fill a flat-sided quart bottle full of water, and invert in it a pill bottle containing just enough water to allow it to float. Cork the large bottle, and adjust the stopper so that the little bottle inside will just float. Press on the sides of the big bottle. Since the glass is elastic, the sides will give slightly, forcing water up into the little bottle, and slightly compressing the air. The bottle will sink. If the pressure is relieved, the compressed air will expand, forcing the water out of the little bottle, which will rise.

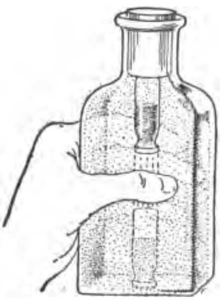


FIG. 101.

A submarine has large air tanks. When water is pumped into them the submarine sinks. It then displaces a weight of water less than its own weight. When the submarine is to rise the water is forced out from the air tanks. The submarine then displaces a weight of water greater than its own weight—a result which causes it to rise to the top and float.

Hydrometers.—Because a body sinks in liquid until the weight of the liquid displaced is equal to the weight of the body, an instrument called the hydrometer may be used for measuring the specific gravity of *liquids*. The hydrometer is usually a slender glass tube, sealed, and

with a bulb at one end containing some heavy substance such as mercury, or shot. The weight helps to keep the instrument in a vertical position. The tube is graduated, like a thermometer, the zero mark being at the depth point of the instrument when floating *free* in *water*. In any other liquid than water the hydrometer will sink deeper or less deep than zero, according to the liquid's density. From the depth to which the hydrometer sinks the specific gravity of the liquid may be told.

FIG. 102.

There are three classes of hydrometers:

1. The *specific gravity hydrometer* indicates the number of times heavier the liquid is than an equal volume of water.

2. The *per cent hydrometer* indicates the per cent of a substance present. This hydrometer is used for determining the per cent of alcohol, water, etc.

3. The *arbitrary scale hydrometer* indicates the concentration of strength of a substance. The lactometer is an example of this hydrometer, and is used for measuring the specific gravity of milk.

Look up uses of hydrometer. What does the word hydrometer mean?

Water Pressure.—Since a cubic foot of water weighs about $62\frac{1}{2}$ pounds, the greater the depth of water in a reservoir or tank, the greater will be the pressure on the bottom and sides of the container.

For every $2\frac{3}{10}$ feet increase in depth the pressure increases 1 pound per square inch, equals .434 lb. per sq. in. for each foot in depth (or for each 10 feet in depth, 10 times .434 = 4.34 lbs. per sq. in.). If an object were 10 feet under water, the pressure on that object per sq. ft. would be 10 times $62\frac{1}{2}$ pounds (625 lbs. per sq. ft.) or 4.34 lbs. per sq. in.

This water pressure is so great in the ocean that divers and submarines are unable to go to any great depth. The greatest depth on record to which a diver has gone is slightly over 300 feet.

What would be the pressure on a human being 300 feet under water?

Fish have been caught in the ocean at the depth of 3 or 4 miles. It was only recently that scientists were convinced that life could exist there, the belief theretofore having been that the enormous pressure at great depths precluded the existence of living beings.

Use of Water Pressure.—Water pressure is used to turn water wheels, to run machinery in factories, in electric generating stations, etc. The most popular type of water wheel to-day is the **turbine**.

Water pressure is used also for supplying cities and towns with water piped either from reservoirs or from lakes higher than the town. The water may (as in many places) flow into a standpipe higher than any of

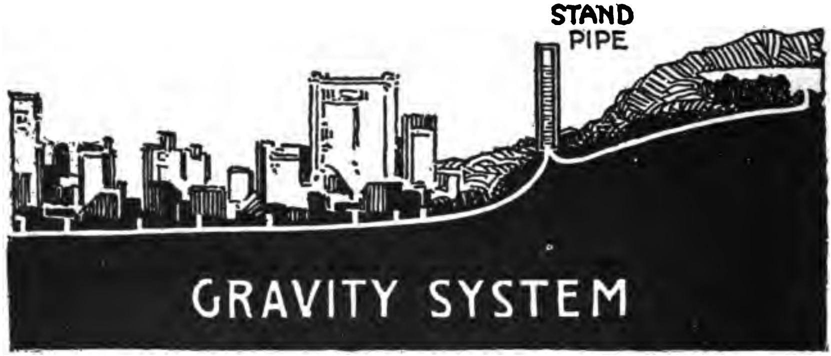


FIG. 103*a*.—Why does the water in the standpipe never run over the top? Why is it necessary to have the standpipe higher than the houses? How far away is the standpipe or reservoir from your home?

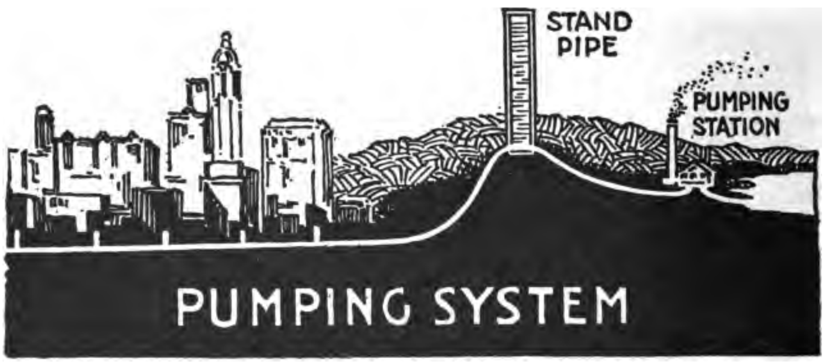


FIG. 103*b*.—Why is it necessary to have a pumping station? What kind of pump would be used in a pumping station?

the buildings in the town. Or, if a reservoir is at a too low level (as in many other places), great force-pumps may be used to pump the water from reservoirs into a standpipe.

The diagrams (Figs. 103*a*–103*b*) exhibit two different methods of supplying towns with water. It will be seen that the water coming from faucets on the top stories

of high buildings will have less pressure than the water coming from faucets on the bottom stories. Moreover, water pressure is reduced by friction of pipes, joints and valves.

Wherever towns or cities are located near mountains the water is piped from lakes or streams that have an elevation greater than the place supplied. Such a system is called a **gravity system.**

If cities or towns are located in level places where there are no elevations from which to get water, the **pumping system** is used to force the water into standpipes or reservoirs higher than any building in the town.

Amount of Water Used.—Although the amount of water required daily for each person in a family is estimated at from one gallon to four gallons, some towns construct water plants which are able to furnish fifteen gallons of water per person. In some large manufacturing places water plants are so constructed as to furnish 200 or more gallons for each inhabitant.

Experiment to Show Water Pressure.—Heat a piece of glass tubing until it is soft. Draw it out to a small jet. Attach one end of the jet to a rubber hose, and place the other end in a dish of water. Fill the tubing with water by sucking the air out. Hold the jet upright but having the dish considerably higher than the jet. Raise and lower the dish of water to represent a lake or other source of water supply at different levels.

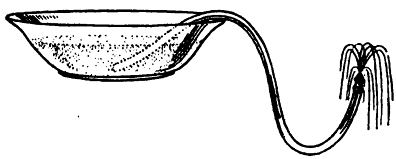


FIG. 104.

What is the relation between the height of the source of water supply and the jet? What is necessary that we may be supplied with water from our faucets?

QUESTIONS

1. Why is it possible for a person to float in water?

2. How much do a boat, engine, people, and material on a boat weigh if the boat displaces 10,000 cu. ft. of water?

3. When you get into a rowboat how much more water must the rowboat displace?

4. Why is it easier to swim in salt water?

5. Would a body a cubic foot in size weighing 125 pounds float in water?

6. Why is water more likely to enter the ear during a deep dive than during a shallow dive?

7. Why will a submarine float?

8. What must be done to make it sink?

9. Why is a fish with a swimming bladder able to rise and sink in water?

CLEANING OF FABRICS

Water as a Solvent.—Water is a solvent for many things, but not for such substances as grease, oil, fat, tar, etc. Dirt or spots on clothing which water will not remove are usually of a fatty or oily character. A mixture of soap and water, however, is a solvent to which many such spots will yield, the dirt forming fine particles which then can be washed out from the cloth.

Whenever oil is shaken with water it breaks up into fine bubbles (globules) which give the water a turbid appearance. Soon, however, the water and oil will separate. If a substance had been added to the water to prevent the oil and water separating when the oil and water were mixed, the result would be called an **emulsion.** Soap is one of the best of the emulsifying agents.

Benzine, naphtha, gasoline, and ether are often used, to dissolve grease, oil, tar, etc., which water, or soap and water, will not dissolve.

Cleaning of Fabrics.—These liquids (benzine, etc.) and other volatile liquids, such as turpentine, are so inflammable and so volatile that they are dangerous to use. For safety's sake one should refrain from using any of them in a room where there is a light, or a fire of any kind; and even out of doors they should not be used except at a distance from a fire.

Soap.—There are many different kinds of soaps. **Floating** soaps are made by beating air bubbles into the soap. **Marine** soap is made from palm nut or cocoanut oil, and readily forms lather with sea water. **Medicated** soaps are of great variety as to medicinal content, such as carbolic acid, tar, etc. **Scouring** soaps usually contain fine sand, ground slate, or pumice.

WATER SUPPLY

Measurement of Water Supply.—Water is sold to the public by two methods:

1. The flat rate.
2. The thousand-gallon method.

If water is sold by the second method the quantity is measured by a water meter, located in the supply line from the water main to the consumer's building, opposite the place or in a man-hole under ground in front.

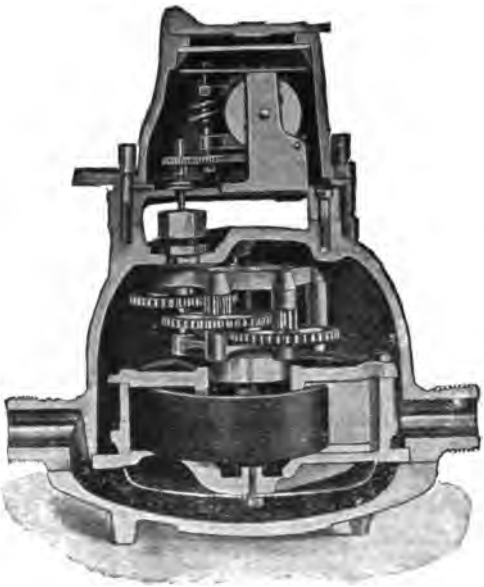


FIG. 105.—X-Ray view of a water meter.

Accuracy of Meters. It is seldom that a water meter over-registers. Occasionally, however, some disarrangement of the meter from dirt entering the working parts may slow the meter down and cause it to under-register. There is also a small amount of unavoidable leakage which sometimes totals enough to cause the meter to under-register.

Meters register in cubic feet or in gallons. One cubic foot is taken commercially as equal to $7\frac{1}{2}$ gallons.

FIG. 106.—Dial of a water meter

Determination of the Amount of Water Required for Any Appliance. One may determine the amount of water required for watering a lawn by turning on the water, and allowing the hose to run one-half hour, reading the meter at the beginning and at the end of the period, and then subtracting the first reading from the second.

If water is being wasted through some leak, this can be easily detected by observing the hand on the circle marked "1 foot," and computing the amount of water wasted per day or month.

Leaks and Faucets.—Water faucets are provided with replaceable valve discs which occasionally must be renewed because of the constant wear. When a disc is worn thin, water begins to drip from the faucets—an action which may cause a great deal of waste.

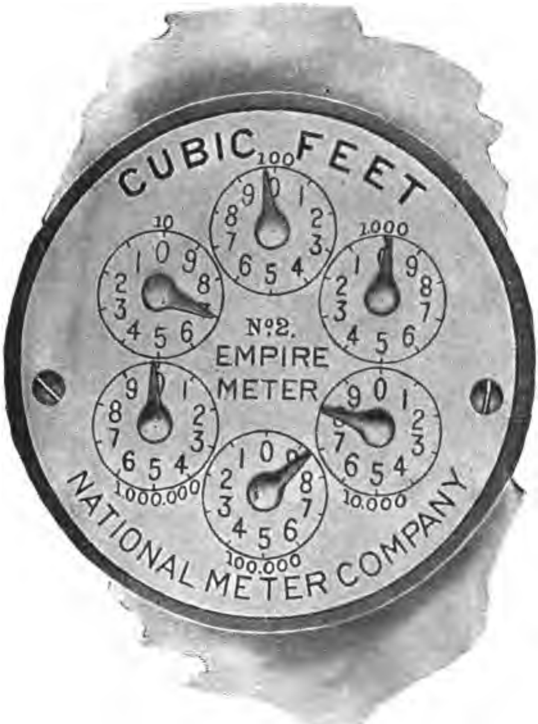


FIG. 107.—Dial of a water meter.

Experiment to Determine the Amount of Water Lost through Faucets Dripping.—Turn on a faucet slightly, and measure the amount of water in pints, quarts or gallons which may run out of the faucet in fifteen minutes. Determine the amount that would run out in twenty-four hours. Determine the amount for a week, month and year. Find the cost of your water supply, and determine from this the loss for the periods of time mentioned above. Turn on the faucet so that a very slight stream runs. Try several different streams, from slow dripping to a stream the size of a pencil.

Sources of Fresh Water.—Fresh water may be obtained from:

1. Rain water.
2. Lakes and rivers.
3. Springs and shallow wells.
4. Artesian wells.

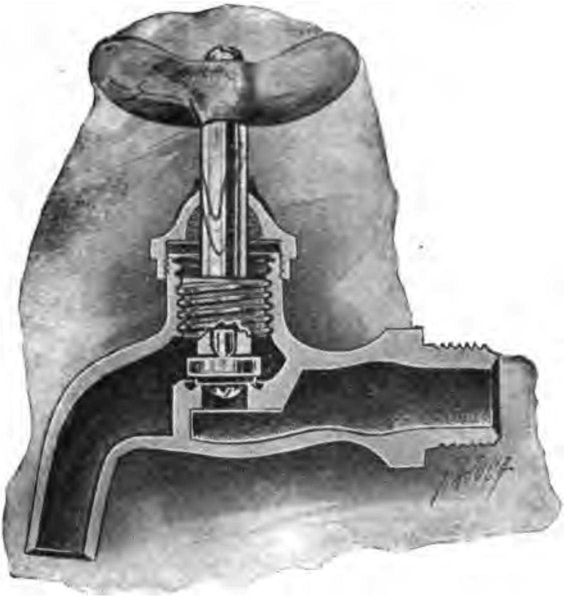


FIG. 108.—What part of this faucet requires renewing occasionally. What allows water to run from the pipe when the screw is turned?

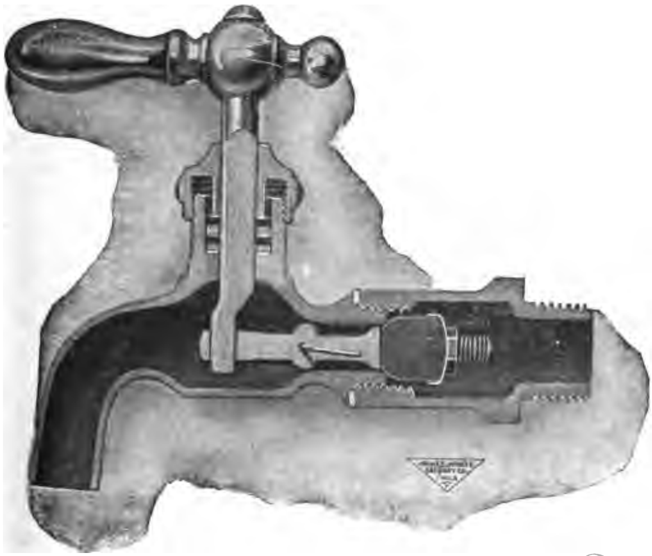


FIG. 109.—What part of this faucet must be renewed whenever there is a leak? What causes the water to run from the pipe?

Not all water which looks clear is pure. Wells and springs may often contain surface water which has been contaminated. Sparkling spring water may be unsafe to drink. Artesian well water, however, is usually pure, since the water at so great a depth in the earth has been thoroughly filtered by the materials through which it has seeped. Such water usually contains many mineral compounds.

Test of Impurities in Water.—Water may be contaminated by:

1. Organic matter.
2. Leaf mold.
3. Vegetable matter.
4. Animal matter. (Sewer contamination.)

Heating Test.—Heat a little water in a corked flask. Do not bring it to boiling point. Shake, remove the stopper, and smell the contents. Pure water is free from odor.

Test for Organic Matter, Animal or Vegetable Matter.—Add to a small amount of water in a test tube a few drops of sulphuric acid. To this add a small amount of potassium permanganate until the water takes on a decided color. Boil. If the water remains the same color, no organic contamination has taken place, but if the water changes to brown, or becomes colorless, there is organic contamination, either animal or vegetable.

Ammonia Test.—To a small amount of water in a test tube add a little Nessler's reagent. A faint yellow tinge only should be visible. A turbid appearance indicates animal contamination and that the water is dangerous to use. All natural water contains a very small amount of ammonia but not enough to cause more than a slight coloration with the above test.

Rain water, although practically pure if properly collected, contains a considerable amount of ammonia dissolved from the atmosphere.

Lead in Water.—Sometimes water standing for some time in the pipes dissolves the lead from lead pipes. In the morning we should let the water (particularly warm or hot water) run for a while from the faucet or fountain, to avoid drinking the water that has been standing in the pipes overnight.

Hot water from kitchen boilers not in constant use should not be used for drinking-water, since lead, copper, and brass are to some extent soluble in hot water, and most of the pipes, the faucets, the boilers, etc., contain one or another of these metals.

Soft Water.—Some waters act on lead pipes, especially soft well waters which contain much dissolved carbonic acid.

If a water causes a coating to form on the interior of a lead pipe, there is little or no danger of lead poisoning, because the coating protects the metal; but if the lead stays bright it indicates that the metal is being dissolved, a fact which will make the water dangerous to use.

Hard and Soft Water.—Water is often called hard if the suds from ordinary soap will not form in it. It is difficult to cleanse clothes in hard water.

There are two kinds of hardness, (1) temporary hardness, which can be removed by boiling the water; (2) permanent hardness, so called because boiling will not render the water soft. If washing soda or soda ash is added to such water, the effect is to soften it.

Purification of Water.—Water for many cities and towns is purified by sand filtration.

Very fine sand is placed at the top of the filter and coarse sand at the bottom. The water passes through the sand—an action which removes the impurities and a great many of the bacteria. These filters are "washed" by forcing water through them in the opposite direction.

Boiling is another method of purifying water. Boiling kills the bacteria, but does not remove the impurities. In the home the boiled water may be placed in stone jars to cool. When water is boiled the air is expelled from it. If the boiled water is let stand a day or so it will absorb fresh air and again be palatable.

Distilling, still another process for purifying water, not only kills the bacteria, but removes all impurities, since the water is changed into steam and condensed again to water. Rain water is nature's distilled water. In some localities the rain water is caught in cisterns and used for drinking water.

House Filter.—House filters for faucets are practically useless. They may be dangerous. One worth while is the Pasteur-Chamberlain, made of a baked clay tube surrounded by a metal tube.

In this appliance the water filters through the clay into a receptacle used for storing it. The filter must be washed daily and baked every week.

Drinking Fountains.—There is little excuse to-day for having the common drinking cup in any school or public building. Where drinking fountains are not possible, individual drinking cups may be used. Many diseases may be carried through common drinking cups. Figs. 110 to 114 teach valuable lessons about drinking fountains.

1. Why are common drinking cups and common towels dangerous?
2. Why should the water of a drinking fountain bubble at least two inches above the fixture?

Fig. 110.—A danger always present in this type of drinking fountain is that of breaking the teeth of one child if another playfully pushes him when drinking. Also, it may prove to be more unhealthful than the common drinking cup. Bacteria will remain in the little bowl. Even when the water runs continually, bacteria will still be present in the bowl.

Fig. 111.—This type of drinking fountain obviates the danger of having the teeth broken. A person drinking cannot get his mouth in contact with the metal. There is no bowl for the water to run back into, so that the bacteria have no place to stay.

3. Why should the force be sufficient to prevent the lips from touching the cup?

4. Why should the cup be of material that will not rust?

5. What kind of material is best for the fixtures?
6. Why should the stream of water be steady?
7. Why should the discharge for waste water be large?
8. Why should a drinking fountain close automatically?
9. Where should drinking fountains be located? Why?

FIG. 112.—This type of drinking fountain is unsatisfactory. The hands may be dirty, and dirt may collect about the mouthpiece. The person may touch his or her lips to the metal. Children have been known to put gum, sticks and other dangerous material in the bowl of such a fountain.

10. What is the law in your state regarding drinking fountains and drinking cups?

11. Why are a number of small sprays meeting at a point better than a large stream bubbling up?

FIG. 113.—A drinking fountain in which the drinker's hands are in the proper place The water is turned on at a distance from the aperture and jet. A number of fine sprays meet at a point near the center of the drinking piece. This fountain is clean and sanitary.

12. Why should the place for hands be as far away from the mouth as possible?

Cisterns.—Cisterns for storage of water should be so constructed as to be readily inspected, and should be cleaned occasionally. They should be made of brick or wood, lined with tin or cement, and provided with an overflow pipe for allowing the excess water to run into a drain.

Wells. —Wells should be closely covered, and provided with a stratum of earth sloping away from the mouth of the well, to divert ground water which might carry pollution. The boards or other covering of the well should be tightly fitted together so as not to allow any cracks, thus excluding various carriers of pollution.

Toads, moles, or insects are liable to tunnel through the cool moist soil by the well and fall into the water, in this way producing contamination. Cesspools, barnyards, hen-houses and outhouses should be so located that no water draining from these places may lead toward the well. Wells should be cleaned often.

Fig. 114.—A drinking fountain for keeping water cool.

Rivers and Streams. —Great care should be taken by all health authorities that no impure matter is placed near streams or lakes from which water is being drawn for drinking purposes. Epidemics of typhoid fever have often been started by the draining of water into such streams or lakes from places which have been polluted.

Sewer Gas.—Sewer gas, whether noxious or not, is very unpleasant to have in the house. Therefore vents must be so constructed that no

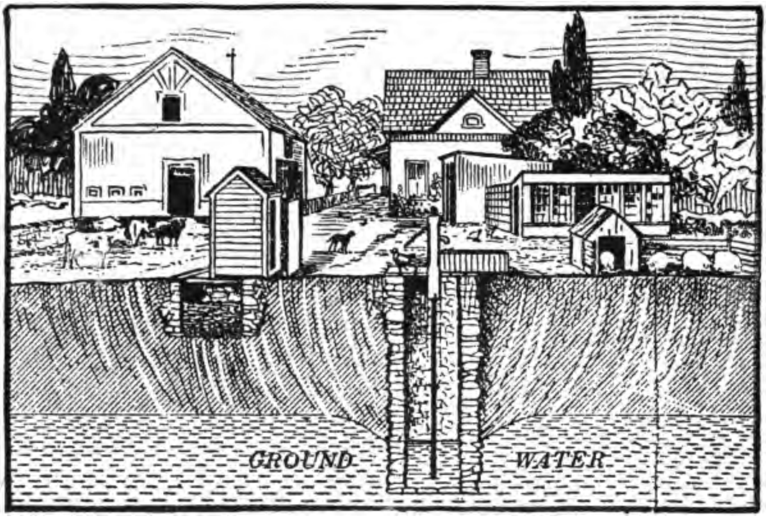


FIG. 115.—Why is a well of this type dangerous? What diseases do you think people might get from drinking the water? Where would be a better place for the well?

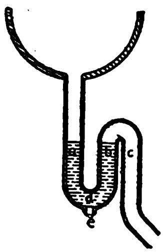


FIG. 116.

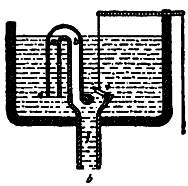


FIG. 117.

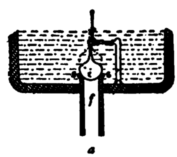


FIG. 118.

FIG. 116.—A hand basin and water trap. Why does material collect at *d*? Why is there a nut at *e*?

FIG. 117.—A tank for flushing a closet. By pulling the string the trap is opened, causing water to run down the pipe *f*. This causes a partial vacuum at *b*, since some of the air will go out with the water. Water rises in *a*, and flowing into *b*, produces a siphon as soon as the trap is closed.

FIG. 118.—Another type of tank for flushing a closet. The bulb at *ss* is pulled up, allowing water to run down the pipe *f*.

gases that form in or collect in the drainage pipes may enter the rooms, but shall be conducted or forced outdoors. Fig. 121 shows the arrangement for discharging the sewer gas by means of a soil stack or vent stack through the roof. The soil pipe passes from the sloping drain pipe up through the house and well above the roof.

Traps.—Traps must be provided for all fixtures which are attached to drain pipes. The bent part of the pipe is called a trap. A small

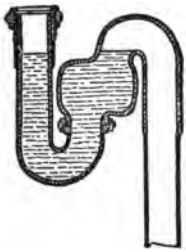


Fig. 119.

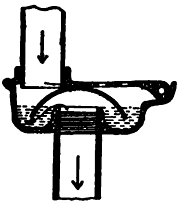


Fig. 120.

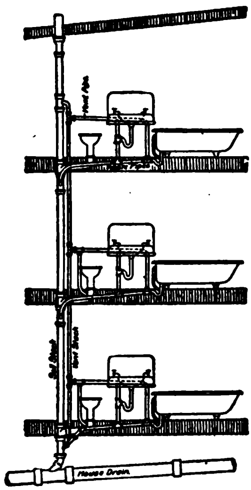


Fig. 121.

Fig. 119.—A water trap. How does the water prevent sewer gas entering the house?

Fig. 120—A water trap for a refrigerator.

Fig. 121.—Why is it necessary to have a vent stack through the roof? Why is each fixture furnished with a water trap?

amount of water must remain in this in order to prevent gases from passing from drain pipes into the house.

Peppermint Test.—Sometimes sewer gas without odor enters the house because the soil pipes are not perfectly sound. If there is any suspicion of this, a simple test may be made by pouring two ounces of peppermint, followed by a pail of hot water, down the soil pipe through its opening above the roof. If all the joints leading to

the drain pipes are not perfect, the odor of peppermint will be detected in the house. The aperture of the soil pipe should be covered during the test.

Fixtures in the House.—Fixtures for the water supply in the house should be made of enameled iron or porcelain. They must be easy to clean, and all parts easily accessible for repairing as well as cleaning.

Facts to be Remembered.

1. Pure water is a luxury.
2. Pure water is a necessity.
3. Pure water is cheap.
4. Impure water is dangerous.
5. Impure water is expensive.
6. Ground-waters must be protected.
7. Surface-waters must be purified.
8. Qualities to be sought in water—cleanliness, softness.
9. Filtration has been justified by experience.
10. Filtration makes water clean.
11. Filtration makes water safe.
12. Hard water may be softened.

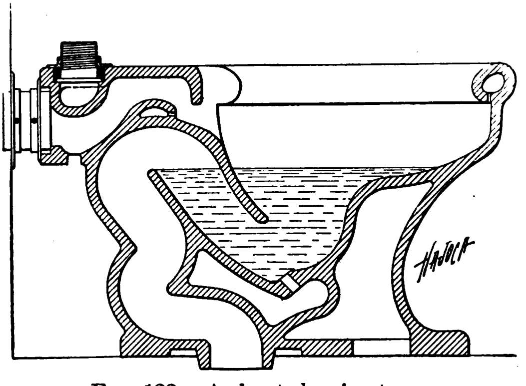


FIG. 122.—A closet showing trap.

QUESTIONS

1. What is the most dangerous source of water pollution? Why?
2. Objections to the use of hard water? Soft water?
3. Why not drink the hot water from the boiler?
4. Precautions to be taken if water comes through lead pipes?

5. If you drink early in the morning at a fountain what should you do first?

6. Give two reasons why the lips and the teeth should never touch any part of the fountain.

7. Examine the fountains in your building. Report.

8. Why is ice from ponds objectionable in drinking water?

9. What care should be taken of wells? Of cisterns?

10. Regarding several wells you know of, tell whether they are properly or improperly located?

11. Why are fire hydrants necessary in cities?

12. Where is the hydrant nearest to your home?

13. What would you do in case of fire?

14. Why is it necessary to connect fire engines to hydrants?

15. What provision is there in your home against sewer gas?

16. How would you test the drain pipes for sewer gas?

CHAPTER IX

GERMS AND DISEASE

GERMS

Protozoa are one-celled *animals* of microscopic size. The one cell performs all the functions necessary for the life of the protozoan. They are the smallest of animals, and look like a mere speck of clear jelly, visible only under the most powerful microscope. Even the larger ones can barely be seen by the naked eye. Protozoa live abundantly in water, but they also grow in the bodies of men and animals.

Bacteria are one-celled *plants* visible only through the compound microscope. They are everywhere—in the air, water, and soil, as well as in the bodies of living animals and plants, and in products obtained from them. Bacteria cause decay, sometimes a fermentation, and cause many diseases of plants and animals. Certain kinds of bacteria are **germs** or **microbes.** Many bacteria are harmless, but there are about twenty which are capable of producing disease in man.

Useful bacteria cause decay of dead matter which can then be used by growing plants. In the preparation of vinegar, cheese and butter, bacteria are necessary. Food for certain plants can be produced only by bacteria in the soil. (More about these, farther along).

There are two classes of bacteria:

1. **Saprophyte,** a micro-organism which derives its food from decaying animal or vegetable matter. Examples are: mushrooms, and mold on bread or cheese.
2. **Parasite,** an organism which inhabits another organism. For example, nearly all of the disease-producing bacteria are parasites.

Shape.—There are three forms of bacteria: the rod, the sphere, and the spiral.

Motion.—Bacteria have motion, due to the presence of hairlike appendages called **flagella** (flah-jel-ah) which, by a lashing movement, enable them to move through fluids.

Spores.—Following a favorable period of reproduction, certain bacteria enter into a stage known as **spore-formation,** a single cell usually producing one spore. This is a resting stage.

The spores offer extraordinary resistance to heat, chemicals and disinfectants. When conditions again are favorable, the spores again enter the reproductive state, but may remain dormant for an indefinite time, as in the case of a typhoid patient, who, after months or years, suffers a recurrence of the disease.

Multiplication of Germs.—When germs have fully developed, a fission takes place which divides the cell into two equal parts. These in turn divide into two parts each. As the fission occurs rapidly, sometimes as often as once in 20 minutes, the multiplication is enormous, sometimes amounting to millions in a day.

How Germs Enter the Body.—Germs may be introduced into the body through:

1. The sweat glands.
2. The hair follicles.
3. The mucous membrane (nose and mouth).
4. Abrasions in the skin.
5. Drinking polluted water or milk.
6. Eating food that contains germs, often deposited by flies.
7. *Mosquitoes* and other insects which carry disease germs.

How Germs Cause Disease.—Germs produce **virulent** (vir′ u lent) **poisons** as they grow in the body. These poisons cause **toxins.** It is the toxins that cause disease.

How the Body Kills Germs.—The white corpuscles of the blood are useful animals. One of their functions in the blood is to kill disease germs.

There is also a substance which kills germs. Every healthy person has a sufficient quantity of this substance in his body for ordinary safety, but not always enough to overcome a great attack of germs. When disease germs enter the blood and begin to multiply very rapidly, more of this **germicidal substance** is manufactured, and it assists the corpuscles in killing the germs. *The turn of a fever* comes at the time when the corpuscles and the germicidal substance get the upper hand of the germs.

DISEASES CAUSED BY PROTOZOA

Malaria.—Malaria is caused by protozoa in the red corpuscles of the blood. They are injected into the body by a kind of mosquito called the **anopheles.** These **malarial** mosquitoes do not travel very far from the place where they breed. The wind often blows the ordinary mosquito great distances, but the anopheles mosquito has the habit of clinging to bushes, shrubs and weeds near the place where it hatches.

The mosquito inserts its proboscis through the skin of a human being, injects into the blood a saliva bearing malarial germs which liberate a toxin that causes malarial disease.

FIG. 123.—The malarial mosquito.
Courtesy of Am. Mus. Nat. Hist.

Precautions against Malaria.—People living in malaria-infected districts should carefully screen their houses, and destroy all places where mosquitoes can breed, such as tin cans, old barrels, and small pools of stagnant water.

Destroying the Mosquitoes.—The mosquito lays its eggs on standing water. In about a day these hatch into wigglers. These wigglers live in the water. They need air to breathe; hence they come to the surface, and thrust out to the air a breathing tube. When the water has been covered with kerosene oil, they are unable to get this breathing tube through the tough film of oil, and must drown.

Smallpox.—Smallpox was, until the discovery of vaccination, one of the most dreaded diseases on account of its extreme contagiousness, its malignity, its loathsome appearance, and disfiguring consequences. Until a little more than a century ago the disease was a scourge, for it attacked nearly every one, the loss of life being enormous. At one time a large percentage of people in England were pock-marked.

Vaccination.—Dr. Edward Jenner of Berkeley, England, discovered the principle of vaccination in 1798.

The germs of smallpox grown in cattle cause a disease called cowpox. In cowpox the germ is so weakened that it grows feebly when it invades the human body, and has only a slight power of producing disease. In vaccination the germs from an infected cow are injected into the human body, where they grow and produce the usual condition following vaccination. The body works up the germicidal substance necessary to kill germs before they make much progress in the body. After this the germicidal substance remains in the blood ready against further invasion. This germicidal substance grows weaker and weaker, and after a few years re-vaccination may be necessary for full protection from the disease. The safest way is to be vaccinated every few years.

Rabies (Hydrophobia).—Rabies is believed to be caused by a protozoan growing in the nerve tissue. The germ infests the saliva of affected animals, entering the human system through their bites. Most cases in this country come from the bites of dogs. In man the germ grows slowly, requiring at least two weeks before the disease shows itself, while the period of development may extend to any time within a year after the bite.

For this disease, Louis Pasteur, a French scientist, discovered a preventive treatment which is usually successful *if commenced in time.* No time should be lost in beginning this treatment, for there is no cure for rabies after the development of the disease. If the materials for this treatment can be procured, the home physician may administer the treatment.

Any dog bite should be promptly treated with the best disinfectant at hand. Burning the wound with nitric acid is the most effective remedy. Even to suck the wound (immediately) may reduce the danger, but pains must be taken to disinfect thoroughly the lips and mouth afterwards, and without delay.

Questions

1. What methods should be used to prevent mosquitoes from breeding and carrying disease?
2. By what means has smallpox been virtually eliminated?
3. Why should a dog that has bitten a person be confined for nine or ten days ?
4. What should be done immediately to a person who has been bitten by a dog?

DISEASES CAUSED BY BACTERIA

Colds.—A "cold" is not a proper name for the disease which we call the "common cold." One may have a "cold" who has not been exposed to cold (low temperature), or has not felt cold or even chilly.

How We Catch Cold.—Colds are a result of the activity of certain germs, probably bacteria, that are always present in the mucous membranes. But the mucus from these membranes has germicidal properties which keep the germs harmless unless the body condition has been altered or weakened so that they may, as it were, get the upper hand. There are two ways of catching cold; first, when the bacteria in the mucus of the nasal passages or pharynx become sufficiently active to cause inflammation; second, when bacteria come from without. The bacteria multiply and soon attack the mucous membrane. The first result is a copious secretion of mucus, nature's method of destroying or washing out the bacteria. This mucous secretion being now deficient in bactericidal properties, only furnishes a better breeding-ground for the bacteria; first we see a thin watery discharge from the nose which, as the bacteria multiply, becomes gradually less watery, assuming a yellowish hue. A toxin, which the germs produce, enters the blood, causing backache, pains in the joints, and general feeling of illness. The body, however, keeps up and speeds up the production of the germicidal substances which in due time overcome the germs, neutralize the toxins, and put an end to the "cold."

Colds are contagious. The infection may come from people in assemblies, school rooms, street and railway cars, and through the use of the common drinking cup, and even from the drinking fountain. Influenza (grip), catarrh and colds are caused by germs, and may be transferred from one person to another.

Diphtheria.—Diphtheria germs live in material which has come from the throat of a diphtheria patient. They attack the tonsils, larynx, nasal passages, and the mouth. A slight attack of diphtheria often causes sore throat only, but if the germs grow rapidly the attack becomes severe in a few days. As soon as the germ enters the body, the body sets about the making of a substance to neutralize the toxin. This substance is called anti-toxin. The anti-toxin does not kill the germ,

but simply counteracts the toxin poison which the germ has produced, rendering it innocuous.

Use of Anti-Toxin.—Anti-toxin may be rapidly produced in the horse. Because of this fact, diphtheria germs are grown in beef broth so as to obtain a supply of the toxin. This toxin is injected into the blood vessels of horses, where large quantities of anti-toxin are generated, nature's provision in the horse, to neutralize the toxin poison. The horse is then bled, the anti-toxin collected, purified and placed in bottles. It may now be injected into human beings, to prevent diphtheria, or to counteract it, and cure those ill with it. To be efficacious anti-toxin must be administered very early in the attack.

Pneumonia.—In the colder parts of our country this disease causes more deaths than any other. The germicidal substance which is worked up by the body to kill the pneumonia germ stays in the blood only a short time; indeed the patient may have a relapse before completely recovering from an attack. A person may have the disease again and again.

The germ cannot be entirely controlled, but anything that builds up the general health is a safeguard against pneumonia. Anything that impairs vitality and weakens the body may bring on the disease, for the germ may be in the throat waiting for something to lower the germicidal resistance. The sputum from pneumonia patients should be destroyed.

To be temperate in all things (including moderation in eating) is to conserve vitality—the greatest safeguard against pneumonia.

Typhoid Fever.—This disease has caused one-fifth of the world's mortality. We contract typhoid fever by taking the germ into the body through the mouth, usually in water or food. Moss-covered buckets, stagnant pools, and wells are common vehicles for typhoid infection. We find the germ also in oysters not strictly fresh, contaminated raw fruit, and polluted milk.

The typhoid germ dies by drying, and is not carried about in the air. The excretions from typhoid patients contain millions of germs, great numbers of which will be carried by flies if all excretions are not destroyed. *Kill the fly!*

Prevention of Typhoid Fever; The House Fly.—The disease is now practically overcome by inoculation with dead bacteria, a method different from that with smallpox, for which living weakened organisms are introduced into the system through vaccination.

Immunity from typhoid fever secured by inoculation lasts about two years. Since this method of combating the disease has been used in the army, typhoid fever has virtually disappeared from the ranks.

The Fly.—The common house fly has received the name of **typhoid fly** because it is one dreadful carrier of the typhoid germ from infected material to foods which people are about to eat. One fly has been known to carry 6,600,000 germs on it at one time.

Flies breed in filthy places. One fly has been known to lay one hundred and twenty (120) eggs in fourteen hours. It takes ten or twelve days for an egg to develop—a dozen generations can be produced in a single season. During one season one fly may be the progenitor of 195,312,500,000 flies, if none are destroyed. *Kill the fly!*

A fly may light on sputum on the sidewalk, or on some other filthy place and then alight on the table where food is about to be served. All garbage should be tightly covered; this is one of the best precautions. Also, for the sake of health, people should avoid expectorating in public places; and people should screen their houses, and use fly traps. Fly paper is another good fly killer.

Build a fly trap and estimate the number of flies that you destroy in one season.

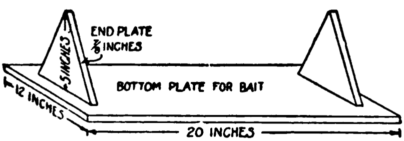


FIG. 124*a*.

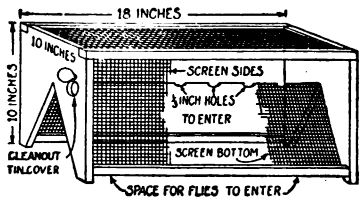


FIG. 124*b*.—A successful fly trap.

For the Good of Your Community.—Check up your yard and your neighbors' yards for the following things:

1. Manure pile.
2. Garbage.
3. Tin cans.
4. Ashes.
5. Weeds.
6. Full privy vaults.
7. Tumble-down shed.
8. Old lumber and rubbish.
9. Dirty chicken- or barn-yard.
10. Neglected well.
11. Uncovered rain barrel or bucket.
12. Tumble-down fence.

Tuberculosis.—More people die of tuberculosis than of any other disease. In the United States every seventh person who dies, dies from this disease.

Source and Origin.—The **bacillus** of tuberculosis may grow in any part of the body, and cause tuberculosis of the part affected. It is slow-growing, but it has great power of resistance against the body's germicidal substances. The bacillus does not grow outside of the bodies of men and animals or the substances they give off.

Tuberculosis of the lungs, which is the most common form, is often called **consumption.** It is caused by the growth and multiplication in the lungs of the minute **tubercle bacillus.** If not checked, these germs spread through one or both lungs, impeding their functions. Everyone breathes in some of these germs at one time or another. If the resistant power of the body against tuberculosis germs has been weakened from any of the following causes:

1. Insufficient food,
2. Living in dark, ill-ventilated rooms,
3. Poor working conditions,
4. Over-work,
5. Weakened condition following severe illness:

the person may be unable to throw off the germs and will contract tuberculosis.

Prevention.—Good health is the best preventive of tuberculosis. To acquire and retain good health we must have plenty of fresh air all the time, eat good food, observe all rules for cleanliness, and be temperate in personal habits. Avoid the breathing of dust. Never put foreign objects of any kind in the mouth. Do not indulge in intoxicants of any kind.

How Contracted.—We may contract tuberculosis either from the milk of diseased cattle or from the **sputum** of a consumptive. Sneezing and coughing cause many germs to enter the air. The sputum must never be allowed to dry, as the germs will then scatter in the air and live for a long time. Spitting in public places should be prohibited. Germ-laden sputum must be destroyed by burning or disinfection. A consumptive person should sleep alone, and, if possible, have a room to himself. It is not dangerous to live or work with a tubercular person if *proper care is taken of the sputum.*

Symptoms.—The most common symptoms of tuberculosis are cough, loss of appetite, gradual loss of flesh and strength, fever, night sweats, and blood spitting. A person who suspects that he has contracted the disease should be examined by a competent physician. If the germs have gained a foothold in his lungs, he should *immediately* obtain the best treatment possible, as tuberculosis, if taken in time, is a curable disease.

Treatment.—The essential factors in the treatment of tuberculosis are:

1. *Rest*: Avoid over-work; sleep a great deal; do not take violent exercise.

2. *Proper food*: Eat three nourishing meals a day; drink pure milk between meals.

3. *Outdoor air*: Sleep out of doors; remain in the open air as much as possible.

No medicine is necessary for the cure of tuberculosis. All advertised **"Cures"** are frauds.

There are many sanitariums where a consumptive can have proper food and care at less expense than at home, and where there is proper disinfection against the spread of the disease. The Board of Health of any city will furnish accurate and detailed information for the prevention and cure of this disease.

Questions

1. Why should all material which comes from the throat of a diphtheria patient be destroyed?
2. What causes cold, pneumonia, and grip?
3. What care should be taken with food and drinking water in order to prevent typhoid fever?
4. State some reasons why flies should be destroyed?
5. Why does the presence of flies denote that there is dirt or filth near by?
6. What value have screens in preventing disease?
7. Why should all table refuse be burned or treated with borax?
8. What relation to the house-fly has a leak in the sewage system?
9. Why should flies be kept out of a room where a person is ill with a contagious disease?
10. Why should stable manure be treated with borax?

Write to the American Medical Association for Booklet on the House Fly.

OTHER DISEASES CAUSED BY BACTERIA

Measles.—Measles is a serious, infectious disease, not only because bronchitis, pneumonia, and tuberculosis may follow the attack, but because permanent injury may be done the kidneys, ears, eyes, etc.

How Contracted.—The germs spread in the watery matter which runs from a patient's nose, and in the sputum. Whenever a person sneezes or coughs or talks, he projects particles from the mouth into the air. Anyone entering the room or approaching the patient may catch the disease. Measles has been contracted from milk, by shaking hands with one who has measles, or by coming in contact with the towels, cups, spoons, or any other dishes used by measles patients. The germs do not live long after they leave the body.

Preventing the Spreading of Measles.—None but the properly authorized attendants should visit the room where the patient is sick. Sterilize dishes and clothes by boiling or by placing them in a 5 per cent solution of carbolic acid.

Write to American Medical Association for information on Measles. Report.

Scarlet Fever.—Scarlet fever must be considered serious even if the patient recovers, because it is liable to cause permanent injury to the ear, kidneys and heart.

Sources.—Scarlet fever germs are given off by the skin, and by discharges of the kidneys and bowels. Since the germs are also in the secretions of the throat, mouth, and nose, the patient will throw them into the air with the particles of moisture when he talks, sneezes or coughs. Letters from the home may carry the malady. Scarlet fever germs may remain alive for months and even years, if protected from air and light. Paper, clothing, letters, bedding, etc., if put away without disinfecting, may be a source of scarlet fever. The milk supply has frequently caused epidemics of scarlet fever.

Write to American Medical Association for information on Scarlet Fever.

Tetanus.—The tetanus or lockjaw bacillus is found in the soil. The dust in the streets, the dirt in our gardens and yards, and particularly the soil around stables contains this germ. It affects horse and man chiefly, entering the body through even slight wounds. The tetanus germ by itself cannot develop if exposed to the air, but, in combination with other germs, it will grow in an open wound.

Wounds caused by anything that has been in contact with the soil, as a sickle, are most likely to develop tetanus; and small but deep wounds, like those caused by rusty nails, make good breeding places for the germ.

Ptomaine Poisoning.—Bacteria throw off waste matter in substances in which they live. Sometimes this material is very poisonous to human beings. **Ptomaine poisoning** is a disease caused by eating fruit, beef, fish and other things in which bacteria have lived and thrown off this poisonous material.

1. Why should scarlet fever be considered a serious disease?
2. Why will tetanus germs die if exposed to sunlight and air?
3. What are some of the sources of tetanus germs?
4. What is the probable cause of the serious illness which sometimes follows the eating of canned food?
5. Why should a wound under a finger nail be carefully attended to?
6. Why should children be kept home from school if one of the family has measles?

BACTERIA USEFUL TO MAN

Useful Bacteria.—We have studied a great deal about harmful bacteria. There are many more bacteria which are useful.

Bacteria in the Soil.—Plants require nitrogen, and obtain it in the simple compounds of nitrates and nitrites. Much of the fertilizer which is put into soil contains an abundance of nitrogen, but not in the kinds of compounds directly available for the roots of the plants. Certain bacteria in the soil, however, attack this material, and change it into the compounds which are directly available as food for the plants. Sometimes the soil has so few bacteria that farmers plant certain types of vegetables on which other bacteria live. On such plants as clover, cowpeas, vetches, alfalfa, the bacteria form knotty growths called **tubercles.** Through the activity of such bacteria, nitrogen is taken from the air and by natural processes transferred to the soil in compounds which fertilize it. Thus the farmers reduce the quantities of expensive fertilizers to be bought.

Bacteria in Milk.—Among the most common bacteria in milk are those whose activities account for the *lactic acid* of sour milk. Lactic acid bacteria are useful in the stomach, as they oppose other bacteria which may be harmful or cause **putrefaction.**

Bacteria in Cheese.—Cheese is usually ripened with the use of molds and bacteria. Some types of cheese, such as limburger, are placed in moist cellars from four to six weeks to allow the bacteria to grow.

Bacteria and Butter.—Some butter makers introduce bacteria into the cream to hasten its ripening (souring, for the churning).

Fresh butter abounds in bacteria. When butter is a day old it contains about one-half as many bacteria as when first produced, and by the second day the number of bacteria has diminished to $\frac{1}{25}$ of the original number.

Send for "Butter and Cheese Making," U. S. Dept. of Agriculture.

Bacteria in Vinegar.—We have learned that the bacteria in bread change the sugar to alcohol, and if bread is not well baked they will change the alcohol into an acid. Bacteria which change alcohol into acids are used to produce the acid in vinegar. "Mother of vinegar" is a mass of bacteria.

Bacteria, Useful for Decomposition.—Certain types of bacteria are used to change dangerous sewage into harmless material. Even disease-producing bacteria are killed by such methods.

Life, which exists upon the earth to-day, depends to a great extent upon the decomposing action of bacteria.

Questions

1. In what ways are bacteria useful?
2. Why is it necessary to have bacteria in vinegar?

METHODS OF PREVENTING THE SPREADING OF DISEASE

Quarantine.—Quarantine is the adoption and enforcement by the proper authorities of measures to prevent the introduction of diseases from one locality into another. People who do not conscientiously keep all quarantine regulations and restrictions are poor citizens.

Patients, ill with contagious diseases, are often quarantined in "isolation hospitals." If the patient must be kept at home, or is allowed to remain at home, the house is quarantined for a certain length of time, depending upon the disease. A placard is placed on the house, and the occupants of the house are restricted in their movements. Regulations are different for different diseases.

Fumigation.—After the recovery of the patient, the room or house must be disinfected to kill all germs. This is usually done by *fumigation* which, to be effective, must be done by an experienced person. In many places the Board of Health attends to it.

How to Prevent the Transmission of Disease Germs.—The *hands* are germ carriers because they come in contact with all kinds of germ-laden articles, as books, pencils, door knobs, street-car straps, and others' hands. Millions of germs can collect under the finger nails. Keep the hands clean, using plenty of good soap. Form the habit of keeping the hands away from the mouth, nose and eyes. Never touch food with soiled hands.

The banishment of the common towel and drinking cup has helped to stop the transmission of disease germs.

Dust is a carrier of germs. Streets should be sprinkled and cleaned. Some damp material should be used in sweeping the floors of public buildings. Houses should be swept with damp brooms, carpet sweepers, or else with vacuum cleaners, to keep down dust. "Dusting" should be done with a damp or oiled cloth that will remove the dust and not scatter it.

Never buy candy or fruit left uncovered to collect dust and germs. All food left exposed to the dust of the air should be properly cleaned before eating. Road-side berries or fruits may have harmful germs in the dust which has gathered on them.

Care of Wounds.—All wounds should be washed with a disinfectant before being "tied up." After bandaging a wound, watch it carefully, for at the first sign of inflammation it must be opened and disinfected. The slightest pricks, scratches, cuts and burns, if not properly attended to, may develop cases of **blood poisoning.** The following disinfectants may be used for treating infected wounds and sores:

Hydrogen Peroxide,* Boric acid, Iodine, a weak solution of Carbolic acid, Carbolic salve, Turpentine, and warm salt solution. For abrasions, surface wounds and the like, "New Skin" is invaluable; it adheres well, keeps out infectious and irritating particles, and is said to have disinfecting properties.

Disinfectants.—A disinfectant is an agent which, properly used, destroys disease germs. It is necessary to use disinfectants around

* Hydrogen peroxide, as manufactured to-day, is not a germicide. Acetanilid is added to keep the solution and because of its affinity for oxygen, free oxygen is not allowed to enter the wound. Great care should be taken when hydrogen peroxide is used as a disinfectant. The oxygen set free from the solution destroys not only the bacteria, but the cells in the wounded flesh. The wound should not be closed up with hydrogen peroxide or dioxide in it because decay of the flesh may take place, causing a great deal of trouble.

sinks and water-closets. Chloride of lime is a cheap and powerful disinfectant for this purpose.

Infected articles of little value, and cloths and papers containing sputum may be disposed of by **burning.** Sterilizing by **boiling** or **steaming** is an effective way to disinfect suspected articles, such as bed clothes, articles of wear, etc., which water does not spoil.

Disinfectants must be used in all cases of contagious diseases. Discharges from the patient must be received in a strong disinfectant, and everything that comes in contact with the patient must be disinfected or sterilized.

Most of our chemical disinfectants are so poisonous that great care must be exercised not to use them internally by mistake.

Direct Sunlight as a Germicide.—Direct sunlight kills the bacteria that are the cause of most human diseases. In fact, direct sunlight is the most powerful germicide known.

Questions

1. Why should people not object to quarantine?
2. Why should all people who are quarantined be glad to obey the rules of the Board of Health?
3. Tell some ways of preventing the transmission of disease?
4. How do you care for wounds at home?
5. When should disinfectants be used?
6. What is said to be the best of all germicides?
7. Why should all rooms be well lighted?
8. What care should be taken of badly soiled handkerchiefs?
9. Why should one wear gloves when traveling?
10. Why should reservoirs be open at the top?
11. Why is it well to have a school room so situated that the sun shines directly into the room during a part of the day?

CHAPTER X

LIGHT AND ITS RELATION TO THE WORLD

LIGHT WAVES

Sources of Light.—The great source of light is the sun (Fig. 76, page 93). We have many minor sources, such as gas, oils, and electricity. Bodies which, like the sun and stars, shine with their own light, are said to be *luminous.* Bodies which, like our moon, and the planets and their moons, shine by reflected light are said to be *illuminated.* Bodies which do not give off any light are said to be *non-luminous.*

How Light Travels.—Scientists believe that light is a kind of motion in the form of waves, not like the waves of the ocean, but waves which travel in direct lines in all directions from the source of light.

It has been determined that light travels at the rate of 186,337 miles per second; at which rate it takes about eight minutes for the light to come to us from the sun. The time required for light to travel to us from the North Star is about forty-six years. This means that if the North Star should be destroyed to-night we should continue to see its light for forty-six years after it " went out." There are some stars so far away that it requires two hundred years for their light to reach us.

Ether Vibrations.—The particular wave motions, or vibrations, which we believe light to be, are supposed to take place in a medium, not air, but intangible as well as invisible, called *ether.* The theory is that the ether fills all space and permeates all matter. The vibrations are conveniently spoken of as *ether vibrations.*

Transparent, Translucent and Opaque Objects.—When light passes through a substance without being diffused we are able to see objects through the substance, which is said to be **transparent.**

When light passes through a substance, like paper or ground glass, and yet we are unable to see objects through it, the substance is said to be **translucent.**

A substance through which light will not pass is said to be **opaque.**

Shadows.—When rays of light are cut off by an interposed opaque body, a shadow is formed, usually representing in silhouette the form of the interposed body.

When the moon is in eclipse it is in shadow, i.e., our interposed body (the earth) has come between the moon and its source of light, the sun. We may say that the earth has "cast its shadow" on the moon.

Sometimes the moon comes between the earth and the sun, casting its (the moon's) shadow on the earth. The people on the moon, if there were people there, if they saw the earth thus in the shadow, might call the phenomenon an eclipse of the earth. But to us on the earth it is an eclipse of the sun.

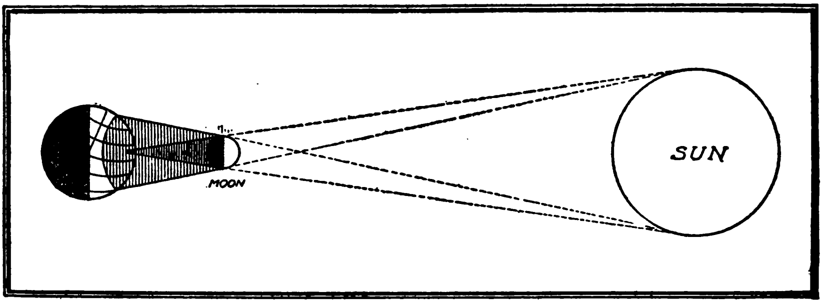


FIG. 125.—Eclipse of the sun.

Shadows are divided into two parts; a dark center called the **umbra,** and a border on all sides of the umbra, of a much lighter fringe, called the **penumbra.**

QUESTIONS

1. Tell what occurs when you cast a shadow?
2. Why are shadows so short at noon?
3. Tell about the shadow and its relation to an eclipse of the moon.
4. How about the shadow when the sun is in eclipse?
5. What causes an eclipse?
6. Why are clouds sometimes black?
7. How are silhouettes made?
8. Can a piece of glass be made to cast a shadow? Explain.
9. Will the shadow increase or decrease in size when one holds an object nearer to the light?

REFLECTION

Kinds of Images.—There are two kinds of images, real and virtual images.

The *real image* is the image formed by the light rays themselves, as when formed by refraction through a lens. A real image can be received on a screen. The images caused by cameras, lenses, by the eye, by moving picture apparatus and projection lanterns are real images.

When a person looks into a mirror an image is seen, apparently behind the mirror. There really is no image behind the mirror. What is seen is called a *virtual image.* The illusion is the result of rays reflected from a plane mirror. A virtual image may not be received on a screen.

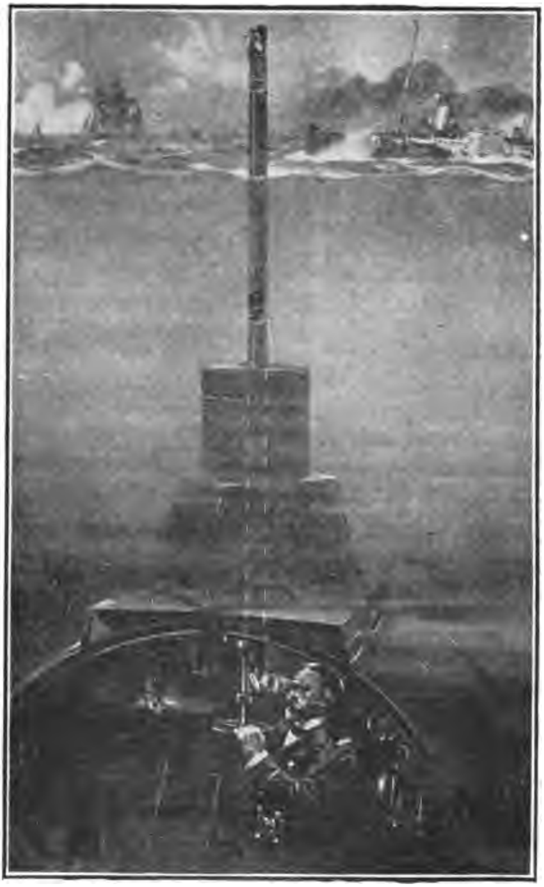


FIG. 126.—Submarine captain looking through the periscope of a submarine.

Why Objects are Visible.—Light shining on the objects about us, such as plants, houses and animals, is reflected into the eyes and enables us to see the respective objects.

The use of a mirror to reflect light so as to produce images is very important in the submarine. The periscope is made up of a round barrel containing mirrors which reflect the light down into the interior

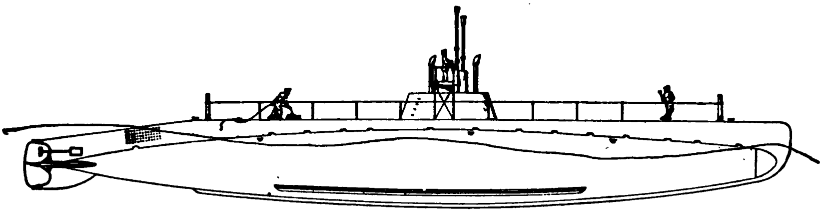


FIG. 127.—A submarine running on the surface of the ocean.

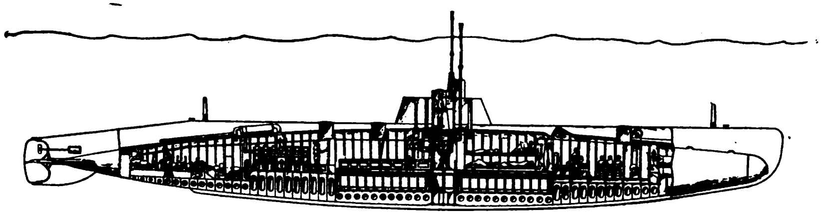


FIG. 128.—A submarine submerged, showing the periscope protruding above the surface of the water.

Formerly, white mice were kept on board to indicate, when they fainted, that the air was getting bad. To-day, air compressors maintain the supply of air in a submarine. How do you think the submarine could be made to rise and sink at the will of the captain? Why cannot the submarine go down to great depths? Why do deep-sea bombs destroy the submarine?

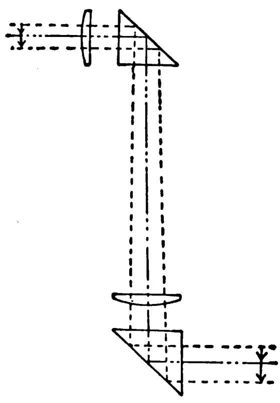


FIG. 128a.—This illustration shows how the mirrors, prisms and lenses produce in a periscope an image. The upper arrow represents the object, the lower arrow the image as seen by the observer.

of the submarine, thus giving a picture of the surroundings when the top of the periscope is above the water.

Mirrors are also used for signal work in an instrument called the heliograph.

With a mirror try to reflect rays of sunlight to different parts of the room.

FIG. 129.—How the moon sends us its light.

The moon is seen because sunlight is reflected from its surface to the earth. Different phases of the moon depend upon the amount of surface toward us which is reflecting light. The new moon is reflecting light with one-half of its illuminated surface toward us.

Law of Reflection.—A person standing directly in front of a mirror sees his own image, but if he stands at the side of the mirror he is unable to see his own image, although it can be seen plainly by a second person standing in a corresponding position on the side opposite, the second person's image also being visable to person number one. The reason for this is easily seen when we know that light is reflected at the same angle at which it hits the mirror. This is in accordance with the law of reflection, and the angle formed by the ray coming to the mirror is called the *angle of incidence;* the angle formed by the ray going from (reflected from) the mirror is called the *angle of reflection*. The angle of reflection always equals the angle of incidence.

Kinds of Mirrors.—Mirrors are divided of two classes, plane and curved. The curved mirrors are also of two types, the **concave** and the **convex.** The mirrors may be spherical concave, or cylindrical concave,

FIG. 130.—Notice a side-view of a photograph from several angles. What view do you always see regardless of the position from which you are observing the picture?

Why does Uncle Sam's finger seem to follow you about the room? Why does he seem to be looking at you in any position from which you may be looking at him?

FIG. 131.

or convex. The concave spherical mirror is used, among other things, for reflecting light upon the teeth, into the throat, and into the ear. It is also used in headlights and for reflectors of lights. The inside and outside of a silver spoon furnish good examples of mirrors of this type. A familar use of the convex spherical mirror is on automobiles so that the driver may see the road behind without turning his head.

Parabolic Mirrors.—Mirrors are sometimes constructed so as to produce a parabolic surface. This causes the rays of light which are reflected from the mirror to travel in parallel rays. This reflector is used in automobile lamps, searchlights, headlights of locomotives, bicycle lanterns and carriage lamps. The light is placed at the principal focus of the mirror.

Questions

1. What kind of image do you see in polished sheet iron?
2. Why do you see an image when you look at the metal?
3. Why do you not see an image when you look at paper?
4. Why is well-glazed paper bad for the eyes?
5. Why is it possible to see an image in a window pane?
6. Why is it difficult to look into a room from the outside through a window when the sun is shining brightly?
7. How does the submarine captain see objects on the surface of the water by the aid of the periscope?
8. What have you about your home in which curved mirrors are used? Explain why.

REFRACTION

Refraction of Light.—If a pencil is held slanted in a dish of water, part in, part out, and looked at from one side it will appear to be broken or bent. This is due to the fact that light rays are bent (*refracted*) when entering the water, which is a denser medium, from the air, which is a rarer medium; also, when they emerge from a denser medium (such as water) into a rarer medium (such as air). When light rays enter a denser medium they are bent downward, causing objects to appear larger, or bent, or broken.

A coin placed at the bottom of a dish full of water seems to be higher up, and if a person looks from directly over the edge of the dish, it is possible to see two images

of the coin at the same time. The image of the sun is seen before the sun rises, because the rays of light, upon entering the air, are refracted by it, the air being a denser medium than that (the ether) in which it was traveling before it came in contact with the atmosphere of the earth. This image is usually large and red. The same thing happens at sunset.

Refraction in a Prism.—Light rays entering glass are bent, since the glass is a medium denser than air. Light rays entering glass made in

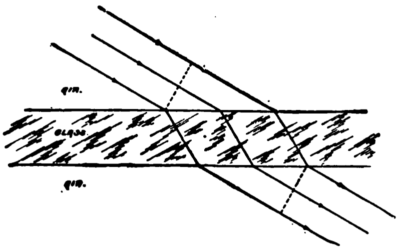


FIG. 132.—How the light rays are bent in passing through a plate of ordinary glass.

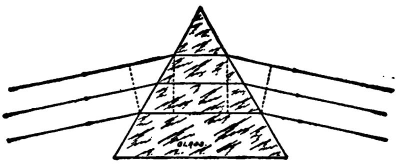


FIG. 133.—How the light rays are bent in passing through a prism.

the form of a prism are bent according to the position the prism is in when the light rays pass through.

In Fig. 134 light rays are indicated as entering the prisms, and then bent so as to be reflected back on the other side of the prism. Use of this is made in instruments called binoculars.

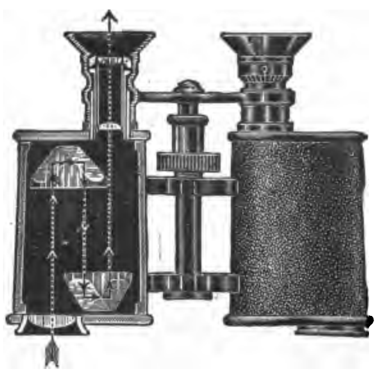


FIG. 134.—Notice how the prism bends the rays of light, causing the light to travel a great distance.

The rays of light are made to pass the length of the barrel three times in going from the objective glass to the eyepiece of each barrel. Thus, by means of a short tube the equivalent of a telescope is obtained.

The prism is used in some headlights of automobiles for bending the rays of light so that they will fall on the road below the vision of the driver of an approaching automobile.

Why a Prism Breaks up Sunlight into Colors.—Light travels through free space (the ether) at the rate of 186,337 miles per second. This light is composed of many colors, as will be seen by placing a prism in the sunlight and looking for the band of color which it produces.

When a light ray passes at an angle into a denser substance, the ray is made to travel more slowly, a fact which causes it to bend. All the colors in the ray, however, are traveling at the same velocity, but each color has a different number of vibrations from the other colors. The longer wave vibrates less rapidly, and consequently is made to bend less; the shorter wave, vibrating more rapidly, is made to bend more.

The Rainbow.—Rainbows generally appear in the afternoon, sometimes in the morning, after a rainstorm has passed over a place. The sun shines upon the falling raindrops which act much in the same way as the prism, breaking the light waves up into the seven colors. No two persons see the same rainbow, as the same drops of rain are not reflecting the same rays of light into the different observers' eyes.

The cut diamond shows much of the same reflection and dispersion of light as the raindrops in the atmosphere. Diamond cutters cut the diamonds so as to get the greatest possible amount of light reflection, refraction, and dispersion.

Color of the Sky.—Outside the atmosphere the sun would be deep blue and the sky black, but the rays of light from the sun, in passing through the atmosphere, have nearly all the blue color sifted out by the atmospheric moisture and dust particles, the resulting appearance being our familiar blue sky. As the amount of dust and moisture increases, different color rays are differently reflected, producing beautiful sunsets and dawns, and often making it possible to "predict the weather."

Sunset Colors.—When, near sunset and sunrise, the light from the sun strikes the earth in a slanting direction, the clouds act as prisms, allowing those colors to pass through which are least turned from their course. Yellows, oranges and reds pass through. The amount and variety of color depend, however, on the thickness and height of the clouds.

A Mirage.—A mirage is an optical illusion which causes distant objects below the horizon to be more or less plainly seen. This happens in regions, such as deserts, when the air near the ground is much hotter than the air above. The lower air, being expanded, is not as dense as the cold air, so that the light rays from the below-horizon objects are successively bent, enabling the observer *to appear to see* the objects. Images seen are inverted. On the Great Lakes, trees, boats and towns on the opposite shore sixty or seventy miles away are sometimes plainly seen.

USE OF LENSES

Lenses.—The ordinary lens is a disc of clear glass, one or both of whose surfaces is curved.

The most familiar examples are the common magnifying glass, the reading glass, the burning glass. One face of a lens may be plane, the other either convex or concave. Or both faces may be convex, or both concave, etc.

Focus of a Lens.—When the rays of light pass through a lens they are bent so as to meet beyond the farther face at a point called the focus.

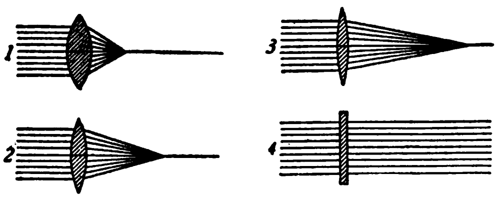


FIG. 135.—What causes the rays of light to meet near the lens and far from the lens?

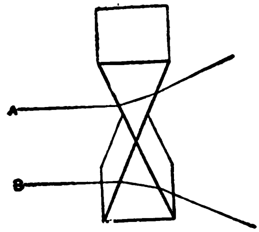


FIG. 136.

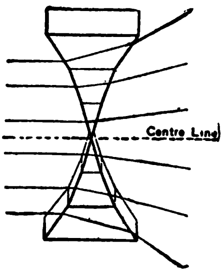


FIG. 137.

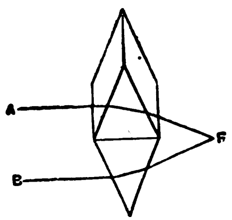


FIG. 138.

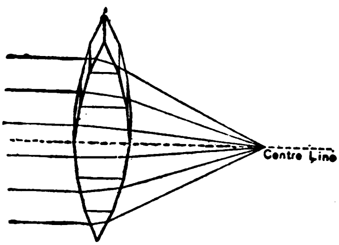


FIG. 139.

Development of convex and concave lenses.

The thicker the lens the nearer the focus is to the lens; and the thinner the lens, the farther away the focus is from the lens.

Effect of Object Distance on Images.—The two principal features of a convex lens are the principal focus and the axis. The stance of the image, and its distance, as produced by any lens, depend upon where the object is placed in respect to the principal focus.

If the object is placed at a great distance from the lens, the image is near the lens, and is small and inverted. Examples of this are the object glass of a telescope, the "view camera," and the eye itself.

If the object is twice the focal distance from the lens, the image is inverted, the same size as the object, and at the same distance from the lens. This plan is often used to make a copy of a drawing when the copy is to be exactly the same size.

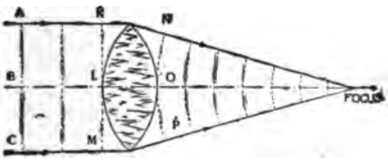


FIG. 140.

FIG. 141.—Appliance to spread the rays for the headlight of an automobile. Study one, and report.

If the object is placed near the lens the image is large. This arrangement is used in enlarging cameras, moving-picture apparatus and stereopticons, reflectoscopes, and the object glass of the compound microscope.

If an object is placed at the principal focus of a lens, no image is obtained. If the object is a light the rays of light pass out of the lens in parallel beams. This principle is applied in the bull's-eye lantern, the lenses for automobile lamps, lighthouses, and spotlights on the stage.

FIG. 142.—The light spread over a road by automobile lamps.

If the object is placed nearer to the lens than the principal focus no image will be formed. The rays of light will spread farther and farther apart.

Condensers in Stereopticons.—Lenses called condensers are used in stereopticons to produce parallel rays. A transparent picture $2\frac{1}{2}$

FIG. 143.

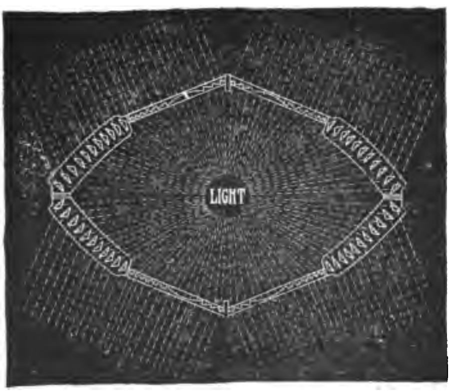


FIG. 144.—The lens of a lighthouse. Notice how each part of the lens is so constructed as to cause the rays of light to pass out in parallel beams.

by 3 inches, called a slide, is placed as near the condenser as possible, so as to be equally illuminated by the parallel rays coming from the condensers. The first condenser nearest the light makes the rays

parallel and the condenser nearest to the lens brings the rays of light to a point, so that they will meet inside the lens called the objective.

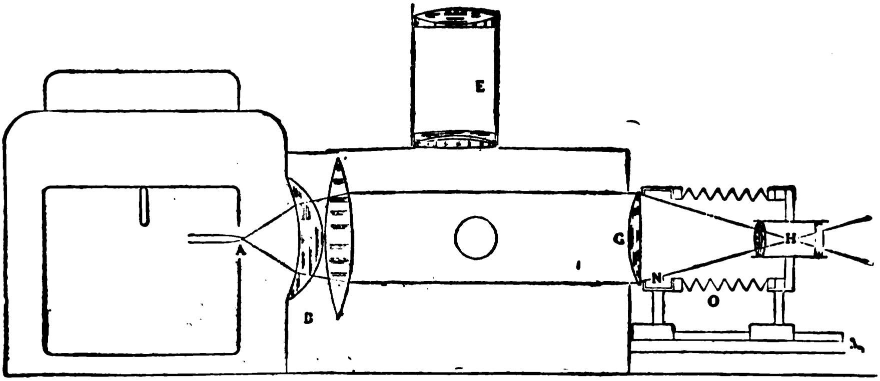


Fig. 145.—How the rays of light pass through the lenses of a stereopticon.

It is possible to tell by the screen whether the light behind the objectives is adjusted properly. Numbers 1 and 2 (Fig. 146) show that the light is not in the center, but too much to the right and left. Numbers 3 and 4 show the results of the light being placed too high or too low. Number 5 indicates that the light is too near the condenser, and number 6 shows that the light is perfectly adjusted, at the right distance and in the center of the condensers.

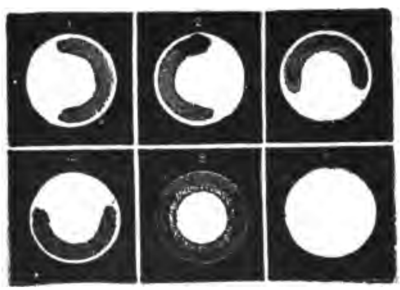


Fig. 146.

Motion-picture Machines.—A motion-picture film is a thin ribbon of transparent material. The photographs (1 in. by ¾ in.) on the film are arranged one after the other, and are slightly different. There are sixteen of these pictures to a foot.

As generally about a foot of film is supposed to be run through a machine each second, the audience sees sixteen different pictures per second. It requires more or fewer than sixteen different pictures to depict a complete change of position according as said complete change of position occupied more or less than a second, e.g. to move the head from one position to another, to lift the arm, or to nod the head.

FIG. 147.—A machine for projecting moving pictures on a screen.

The audience does not see the pictures moving. In fact, each picture is made to stand still for a fraction of a second while the audience sees it; that is, a person in the audience sees each second sixteen different pictures standing perfectly still. If the pictures should not stand perfectly still the picture would look streaked. In order to accomplish this a revolving shutter (731, in Fig. 149) is used in connection with a

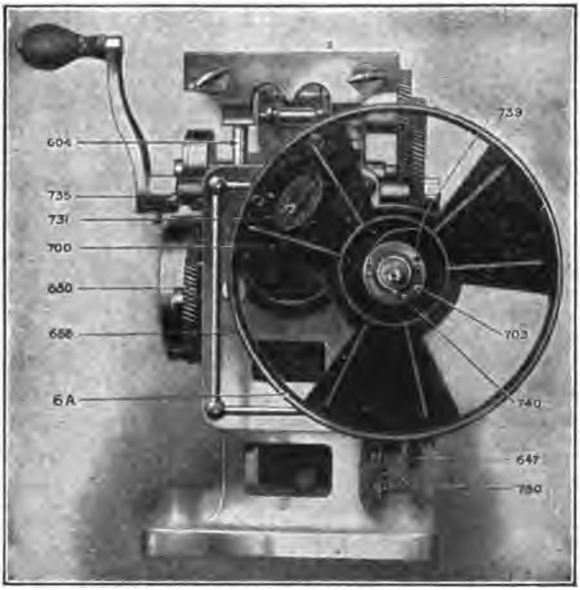


FIG. 149.

mechanical device for making the film move forward in quick jerks. Each picture must come to a complete stop before the shutter uncovers it.

On each side of the film is a margin $\frac{5}{32}$ of an inch wide in which are perforations for sprocket wheels which feed the pictures to the machine.

The Taking of Motion Pictures.—Pictures of moving objects are taken by a camera which takes about sixty pictures per second,

FIG. 148.

FIG. 148.—A part of a film for a moving picture. Each picture is slightly different and if seen in rapid succession the automobile appears to be moving around the street corner.

but, as previously stated, the pictures are not projected as rapidly as that.

This causes strange illusions in certain types of pictures. The wheels of an automobile appear to be going around in the wrong direction. If the pictures were projected as rapidly as they were taken, the wheels would appear to go in the correct direction.

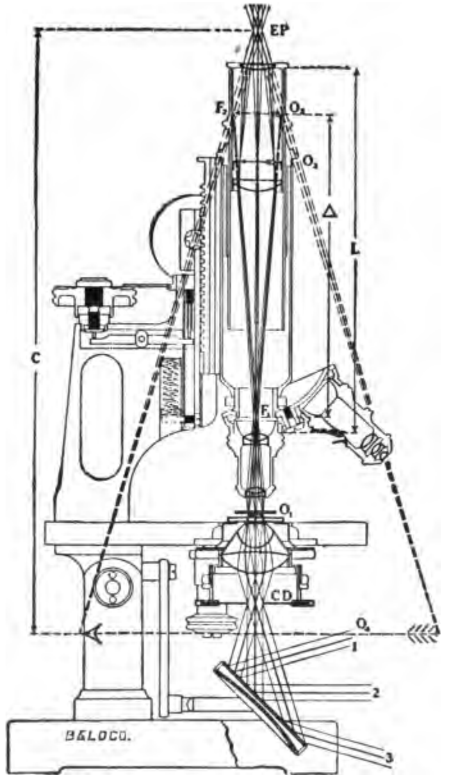


Fig. 150.—A compound microscope. O_1 is the object. O_4 shows how much larger the object looks. What do you think causes the object to form so large an image?

Sometimes comic pictures are taken in which the people travel very rapidly. In such cases the moving-picture camera has taken the picture very much slower than it is ordinarily taken; but when the moving-picture machine, operating at its customary pace, shows the picture, the objects move very rapidly. If opposite results are desired, the pictures are taken at excess speed.

Questions

1. Why does a "bull's-eye light" look very large?

2. Why do fish look large in a globe-shaped aquarium?

3. Why does fruit preserved in cylindrical glass jars look large?

4. Why is it possible to see the sun before it is up?

5. Why does the moon look much larger on the horizon than it does higher up?

6. Why do objects look broken or irregular through some window-panes?

7. Does a stick held slantingly in water look larger or smaller, straight or broken? Why?

8. When do you know that the light in a stereopticon is placed at the right distance from the condensers?

9. Is the image on the ground glass of a camera real or virtual?

THE EYE

Results of Eye Trouble.—Many people suffering from indigestion, headaches, neuralgia, or mental exhaustion often find that such troubles are traceable to the eyes. Children who are wayward, incorrigible, backward, stupid, or defective, may be the victims of eyes which see things out of focus. The proper remedy may be found in properly adjusted glasses.

The constant physical effort of trying to see things clearly with defective eyes uses up a tremendous amount of physical energy and vital nerve force.

Lens of the Eye.—The eye contains a lens which bends the light rays and brings them together at a point on the retina. We have learned

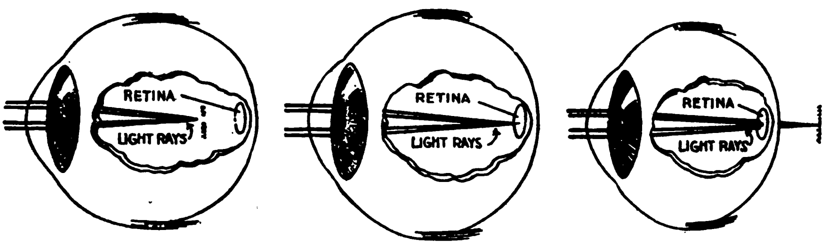
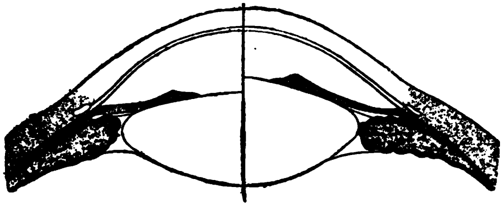


FIG. 151.—Myopia, short sightedness. Emmetropia, normal sight. Hypermetropia, far sightedness.

that a thick convex lens causes the light rays to meet at a point nearer the lens than does a thin convex lens.

Sometimes the eyeball is too flat and tends to bring the rays of light to a point behind the retina. If this is the case, the muscles of the eye must cause the crystalline lens, which is like firm gelatin, to become thicker than usual, and assume a more convex surface.

Sometimes the eyeball is elongated, and the rays of the light do not meet on the retina but at a point in front of it. If this is the case the crystalline lens has to become more flattened.



This side is in a state of relaxation and is for viewing objects at a distance. Why is the lens thin?

This side is accommodated for near objects. Why is the lens thick?

Fig. 152.—Diagram of an eye in the process of accommodation.

When the lens becomes thicker, the eye is then able to focus upon nearby objects. If the eye wishes to focus on distant objects, the opposite happens; the lens becomes flattened.

As one grows older the crystalline lens may become hardened and may not adjust itself for different distances, thus making it necessary

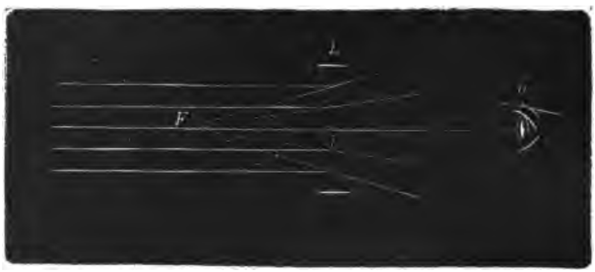


Fig. 153.—A concave lens spreads the light rays.

to wear two kinds of glasses, one pair for near work and the other for seeing distant objects; or else to wear bi-focal (two-focus) glasses.

If a person reads for too long a time the muscles of the eye grow tired because of keeping the lens in a certain position. We often notice the results of tiring the eye muscles when we suddenly raise the eyes from

FIG. 154.—Different kinds of lenses.

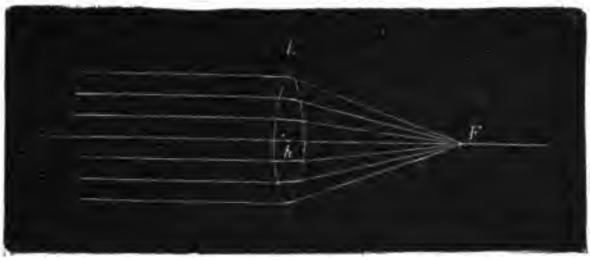
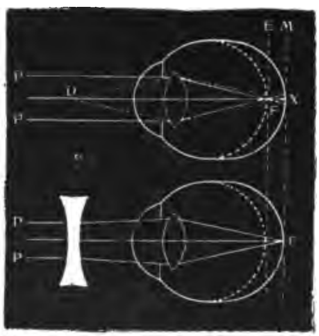


FIG. 155.—A double convex lens brings the light rays together.

a book to some distant object. An appreciable time elapses before the eye adjusts itself so as to form a sharp image on the retina.

Near- and Far-sightedness.—If the eyeball is flattened the person is said to be **far-sighted** or to be suffering from **hypermetropia.** If the eyeball is elongated the person is **near-sighted** or suffering from **myopia.** In both instances the muscles of the eye over-exert themselves in the effort to rectify the sight. Artificial lenses must be placed in front of the eye in order to bring the rays of light to a proper focus without undue effort on the part of the muscles, and incidentally to relieve the eye muscles.



FIGS. 156 and 157.—The focusing of parallel and divergent rays in near-sightedness. The correction of myopia by means of a concave lens.

Snellen Test.—Place the test sheet twenty feet away from the person. Be sure the light illuminates it but does not shine in the eyes. Test each eye separately by holding a piece of black paper over the other eye. If the person wears glasses, make the test with the glasses on. If a person can read the lines marked **15 ft.**, at a distance of twenty feet from the chart, that person is far-sighted. If a person cannot read the line marked **20 ft,** he is near-sighted, and the seriousness of the trouble may be determined by the marking of the line which the person can read. Unless there is a sign of eye strain, the person who cannot read figures smaller than those marked **40 ft.** is seriously affected, and if the line marked **40 ft.** cannot be read, the trouble may be considered still more serious.

Headaches, reddened, crusted, or swollen eyelids, styes, inflamed eyeballs, squinting, blinking, twitching of eyelids, and wrinkling of the forehead indicate possible eye strain. One who is near-sighted, far-sighted, or astigmatic, or who has any of the symptoms named, should consult an oculist right away.

Astigmatism.—This defect of the eyesight results from an unsymmetrical lens or cornea, causing some of the rays of light to be slightly out of focus. Twitching of the eyelids may ensue.

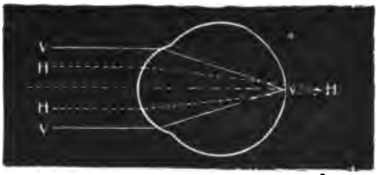


FIG. 158.—Astigmatism. A part of the lens or cornea of the eye is out of the normal position, so that some of the rays, say *H H*, may meet behind the retina; while other rays, say *V V*, may meet on the retina.

Other signs of Eye Strain.—Often a feeling of nausea and a sense of fatigue after a strenuous day's "close" work are due to eye strain.

The cause of the loss of appetite, dyspepsia, and insomnia from which so many school boys and girls suffer may often be traced to defects of the eyes. The strain and fatigue of the eye muscles is communicated to the centers governed by the **pneumogastric nerve,** which has a great influence over the stomach and digestion.

40 ft.

Z B D

30 ft.

F L C T

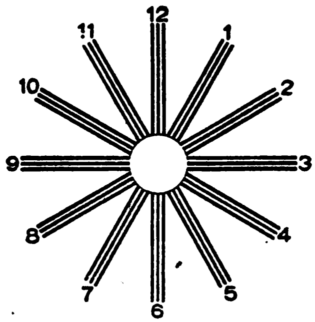
20 ft.

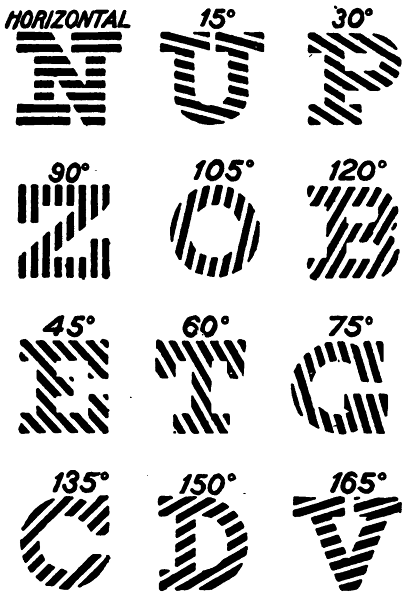
P E O R F D

15 ft.

R T V Z B D F H

Cause of Seasickness.—Sometimes people aboard ship are made sick by the constant changing of the focus of vision caused by looking toward the horizon over the side of the vessel while it is rising and sinking with the motion of the waves. The nerves of the eyes are irritated, and this irritation is communicated to the nerves of the stomach. The result is seasickness. Car sickness is caused in much the same way.





Test for Astigmatism.—To test the eyes for astigmatism hold the diagrams from two to three feet away. Astigmatism is present if some of the sets of radiating lines, or if some of the rows of lined letters are brighter and more distinct than others.

Abusing the Eye.—Many people are careless with their eyes. Two of the most common abuses are lying down in a strong light, and facing a bright light. Also, reading in a moving train causes eye strain by excessive focusing because of the unsteady type. Unsteady moving pictures may cause the muscles of the eye to do more work in a half-hour than they would do in a week of ordinary usage.

The alcohol and tobacco habits may have injurious effects on the eyes. Tobacco smoke is irritating to the lids and to the delicate outer covering of the eyeball.

Objections to Wearing Glasses.—Many people unwisely defer the wearing of glasses because of the dislike to look old. If one has any

trouble with his eyes, he should hasten to an eye specialist and be properly fitted with eyeglasses; this saves a deal of suffering for the present, and possibly permanent injury to the eyes which cannot be corrected later.

Varieties of Lenses.—Lenses for eyeglasses are of three classes: Spherical, Cylindrical, Prismatic.

The spherical and cylindrical are either convex or concave, while the prismatic may be plane or may be ground concave or convex. The characteristics of two or three of them may be combined in one lens.

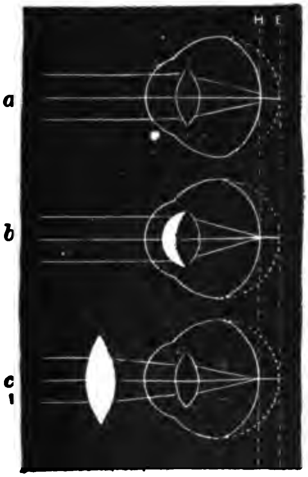


FIG. 159.

FIG. 159*a*.—A far-sighted eye at rest. The rays of light meet behind the retina.

FIG. 159*b* represents rays of light from a distant object focused on the retina by an increased convexity of the lens, the increase being obtained by the muscular effort known as accommodation. In other words, one who has such an eye has to use his accommodation for distant as well as near vision. while the one with a normal eye can save all his accommodation for near work.

FIG. 159*c* represents the error corrected by a convex glass, the necessity for distant accommodation removed and accommodation reserved for near vision.

In far-sighted eyes the rays of light tend to meet behind the retina, but by the use of a **convex** lens placed before the eyes they can be made to meet on the retina. (Fig. 159, *a* and *c*.)

Near-sightedness is caused by the rays of light meeting at a focus in front of the retina. Concave lenses placed before the eyes cause the rays of light to spread and meet again, farther back, on the retina. The lens must be more or less concave according to the individual need. (Fig. 156, 157.)

Flat and Meniscus Lenses.—There are two types of lenses used for the eye. One is called the *flat lens* and the other is the *meniscus*, or *toric*.

People who wear *flat lenses* must look through the center of the lenses to make objects appear clear and sharp; otherwise there will be a hazy and even a distorted appearance at the margins of the lenses. This, undoubtedly, is the reason why some people turn their heads frequently when wearing glasses, or look over the tops of their glasses. The eyes are not stationary. They rotate in their sockets, and one moves them across the printed page, or whatever the field of vision may be, without moving the head. Either the object is magnified too much or too little. The optical scientist identifies this as astigmatism and distortion.

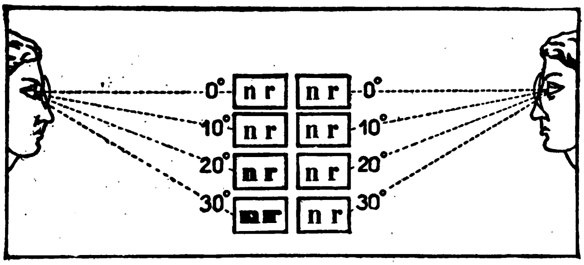


FIG. 160.—The range of perfect vision. Effects through a flat lens, on the left; and through a meniscus lens, on the right.

The *meniscus lens* has spherical surfaces. It is called *toric* if one surface has two different curvatures. The use of this lens allows a clear image to be seen at almost any angle to which the eyes are shifted, without moving the head, thus allowing a more normal vision.

Protect the Eyes.—Too much light, as well as too little, should be avoided. A "soft" light of sufficient strength to afford easy vision without fatigue to the eyes is the ideal illumination.

Avoid severe contrast. For example, a brilliant light against a dark background is injurious to the eyes.

Lamps should be so placed or shaded as to prevent the eye being exposed to bright light sources; and so placed that the rays falling on glazed surfaces shall not be reflected into the eyes.

The source of light should never be in front of a person who is reading. The light should fall over the shoulder or come from the side, preferably the left side.

Books with very shiny paper surfaces often produce injurious effects by reflecting too much strong light into the eyes.

The Iris.—The colored part of the eye is the **iris.** Its function is to regulate the amount of light that enters the eye. The circular opening in the center of the iris is the **pupil.** Circular muscular fibers run around the pupil; and when they contract the pupil is made smaller. Other muscle fibers run in from the outer edge of the iris to the pupil; and when these contract the pupil is enlarged. The size of the pupil is under involuntary control. In a strong light the pupil is diminished, in a weak

Bad *position;* light shining in the eyes, direct reflection from book, chest contracted.

Good *position;* eyes shaded, no reflection from the paper, chest expanded.

FIG. 161.

light the pupil is enlarged to admit more light. It takes a few minutes for the pupil to adjust itself to sudden changes in the quantity of light.

Darken the room. Look at the iris of someone's eye. Quickly bring a candle near the eye. Notice how the iris slowly closes in.

A cat's eyes show very distinctly the changes in the size of the pupil. Examine the eyes of a cat in the light, and after shutting the cat in a dark room examine the eyes again.

Owls have very large pupils which enable them to see at night better than most animals and birds; but a bright light dazzles their eyes, as the pupils can not be made sufficiently small. Many animals, as the cat and horse, can see better at night than man can see, because their pupils can be opened wider than the pupils of the human eye.

The Orbit.—The *orbit* is the bony socket in which are the eye (eyeball) and its accessories. The human eye is well protected in its bony socket. Ordinary blows are received by the prominent cheek-bone below, or the edge of the frontal above. Nothing but a well-aimed thrust of a comparatively sharp instrument can injure it. It is also protected from shocks by a cushion of soft material. The cavity of the orbit is conical in shape, and the space not occupied by the eye and its appendages is filled with loose tissue containing fat.

The Eyeball.—The eyeball has the shape of a sphere, with a segment of a smaller sphere grafted upon it, making the diameter from before

Pupil of eye expanded to let in plenty of light when illumination is dim.

Same pupil contracted to shut out excessive light.

FIG 162.

backward a little greater than the lateral diameter, which is about one inch (Fig. 163).

The eye is apparently set in a slit in the skin of the face, but really this is not the case, for the skin of the eyelids turns over their edge and becomes here a thin, transparent, smooth, and exceedingly sensitive mucous membrane, the **conjunctiva,** which lines the lids and extends over the front part of the eyeball itself so that the eye is really *behind the skin.*

The Sclerotic Coat.—The sphere-shaped eyeball is virtually a globular receptacle filled with transparent fluids. The walls of the receptacle are three in number, close to each other, and called respectively the outer or first, the middle or second, and the inner or third *tunic.* The outer tunic is in two parts, one opaque, the other transparent. That part which covers about five-sixths of the eye and is of a pearly white

color is called the **sclerotic coat.** (Fig. 163, *F*). The part of it which we can see is called the "white of the eye." It is a tough, dense membrane, rigid enough to give shape to the eyeball, yet elastic and yielding to pressure. The muscles of the eye are inserted into it, and it is perforated at the back part for the entrance of the *optic nerve* (Fig. 163, *L*). The existence of nerves in it is doubtful, and its blood-vessels are few in number. The veins we see in the white of the eye when it is "blood-shot" are in the conjunctiva, which is so transparent that we do not see it except when its vessels are filled to excess with blood.

The Cornea.—The *cornea* is the window through which light enters the interior of the eye (Fig. 163, *A*). The cornea is perfectly transparent and fits into the sclerotic coat like the crystal of a watch in its case. In outline it is almost circular. The conjunctiva covers it in front. It contains numerous nerves but no blood-vessels.

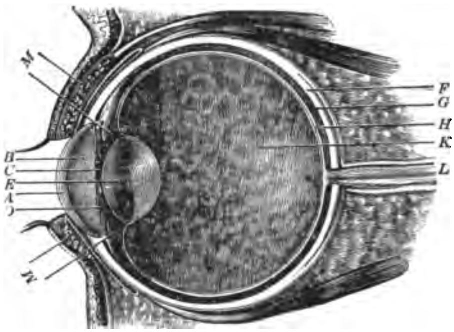


FIG. 163.—A section of the Human Eye. *A*, cornea; *B*, aqueous humor; *C*, pupil; *D*, iris; *E*, crystalline lens; *K*, vitreous humor; *L*, optic nerve; *F*, sclerotic; *G*, choroid; *H*, retina; *M*, eyelids, with Meibomian glands.

The Choroid Membrane.—The middle coat of the eye which lines the sclerotic coat is called the *choroid membrane* (Fig. 163, *G*). Like the sclerotic it is pierced behind for the entrance of the optic nerve.

The Aqueous Humor.—The cavity of the eye is filled by three transparent bodies, called humors. That occupying mainly the space behind the cornea and in front of the iris is called the aqueous humor. (Fig. 163, *B*). A very little of it lies in the space behind the iris, communicating with that in front through the pupil.

The aqueous humor is a clear liquid, consisting mostly of water with alkaline salts in solution. If the cornea be punctured the aqueous humor escapes, the protuberant part of the eye collapses, and the sight is temporarily lost. The wound will, however, heal in a short time and a new supply of liquid will be secreted and sight restored.

The Vitreous Humor.—The large cavity enclosed mainly by the retina contains a thick, jellylike transparent albuminous substance, called the vitreous humor (Fig. 163, *K*).

The Protectors of the Eye.—Not only is the eye well protected by its location, but it has in addition certain guards and defenders. The eyebrows shield it from excessive light and direct the perspiration to one side and possibly intercept some particles of dust that otherwise would get into the eye. The eyelids, composed of cartilage, muscle-fibers, blood vessels, etc., covered with skin and lined with the conjunctival membrane, act both reflexively and voluntarily, closing instantly when danger approaches. Their edges contain small glands (Meibomian glands) which secrete an oily fluid which prevents the tears from overflowing on the face and keeps the lids from adhering to each other. The **cilia,** or **eyelashes,** help to intercept dust, and act as shades to the eye and as feelers to warn of danger in the dark. The **conjunctiva** (page 208) being highly sensitive warns us of the danger of permitting particles to remain in contact with the eye.

The Lachrymal Apparatus.—This is an additional means of protection to the eyes, and provides, for each eye, the lachrymal gland, with excretory ducts, the lachrymal canals, the lachrymal sac, and the nasal duct. The lachrymal gland is located in the upper, outer part of the orbit, and pours its fluid secretion through several ducts upon the eyeball. The constant winking keeps fluid distributed over the eye. Unless too copious this fluid is prevented from flowing off upon the face by the oil from the Meibomian glands. The orifices of the two lachrymal canals open at the inner lower corner of the eye and receive the fluid. They empty it into the lachrymal sac, and this discharges it into the nasal duct which opens in the nasal cavity. Here it evaporates as fast as discharged. When the secretion is excessive it flows past the lids and down the face in the form of tears. The tears consist mostly of water containing salts in solution, common salt (chloride of sodium) being the most abundant. The function of the lachrymal fluid is obvious. It lubricates the contact surfaces, cleanses them, washes away the intruding particles, and provides a buffer layer protecting the sensitive conjunctival membrane from irritating atmospheric conditions—all tending to keep the eyes "clear."

Experiment.—Get from the butcher the eyes from an ox, pig, or sheep. If

possible get several specimens to use in case one is spoiled in dissection, and also that you may try different methods of preparing them for illustration. Place in water until ready for use. With the aid of Fig. 163 examine each part of the eye.

Notice that the *crystalline lens* if placed over print *will magnify* the words.

Two Eyes Better than One.—Close one eye and try to judge distance. It is difficult. One eye acting alone focuses differently than when focusing in concert with the other eye. If with one eye closed you try to point a pencil into a hole that has, say, $1\frac{1}{2}$ times the diameter of the pencil, your judgment will probably again be at fault—as to direction, this time, as well as to distance. Again, viewed with one eye, objects are apt to have a flat look; that is, while having the two dimensions, length and breadth, they seem lacking in the third dimension, depth. Now, facing a wall about a yard distant, hold your hand at arm's length directly in front of your face; close both eyes; open one eye and look at the hand. It will appear to be against the wall; if you are not actually deceived, it is because you know that the hand does not touch the wall. Look again, with both eyes open; the hand now is seen in the open, that is, at a distance from the wall.

The direction of the line of vision from one eye to an object viewed, is slightly different from the direction of the line of vision from the other eye to that object. One eye sees from one point, the other eye from a different point.

When an object is viewed simultaneously by the two eyes from the two slightly different directions; and (the two eyes focusing together) the two separate images are blended into one sensation in the brain, the viewed object presents the effect of the third dimension, depth (or solidity), as well as of the other two dimensions, length and breadth (or flatness). What an object lacks when viewed with one eye is *perspective*. To view it with both eyes simultaneously is, as we say, to give it perspective.

The Blind Spot.—The spot where the optic nerve enters the retina is a blind spot. The most sensitive spot on the retina is called the yellow spot, and is slightly removed from the blind spot.

By closing one eye and looking at the cross in the illustration (Fig. 164), gradually bringing the book toward the face, the round spot will disappear. The image of the dot is now on the blind spot of the eye, just where the optic nerve is not sensitive to light. If the book is brought a little nearer to the face the black dot will reappear.

Why We See Objects Upright.—The image made by a convex lens is always inverted; the crystalline lens of the eye is a convex lens, and the images it makes on the retina are reversed. The sensation produced by the image on the retina is conveyed to the brain by the optic nerve. It is not the image but the object from which the rays of light come, forming the image, on which the eye depends for an impression; and since the eye deals with the outside object, and depends upon the inside image for the sensation, the impression made on the brain is that of the real object, which is upright.

FIG. 164.—There is a blind spot in both your eyes.

Optical Illusions.—A few interesting examples will show how a person may be deceived through the sense of sight. (Study the illustrations and the comments.)

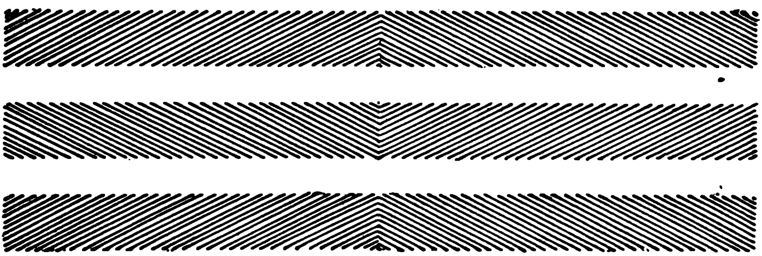


FIG. 165.—Fix your eyes on the two white spaces between the lines. The top space will seem to become wider at the ends, and the bottom space wider in the middle. Both are perfectly straight.

People dressed in white look larger than when dressed in black. Fig. 169 bears on this fact.

If two perfect squares be made, one of horizontal lines and the other of vertical lines, the space covered by the former seems to be greater than the space covered by the latter. This interesting illusion is taken advantage of in decorating rooms and in the selection of dresses. Stout people should not wear dress goods having horizontal stripes, and slim people should avoid dress goods with vertical stripes.

Look through a paper tube with one eye, and holding a hand near the tube. If the other eye is open, objects appear visible through an apparent *hole in the hand*.

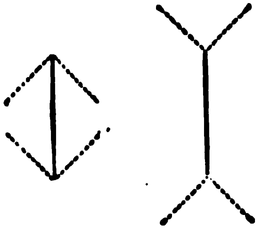


FIG. 166.

FIG. 167.

FIG. 166.—Which of the two vertical lines is the longer? Measure them carefully to make sure.

FIG. 167.—These black circular spots, if looked at intently, will *seem* to have become six-sided like a honeycomb.

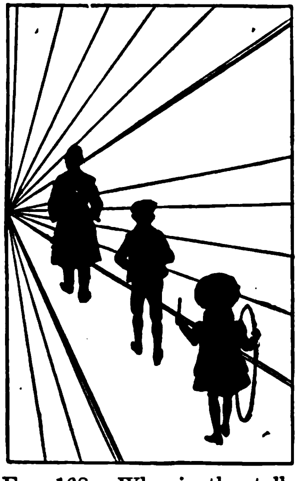


FIG. 168.—Who is the tallest? The policeman, most people would say. Not so! Measure carefully all three.

FIG. 169.—Which square is the larger Most people would say the white, but the white is the same size as the black. Measure them.

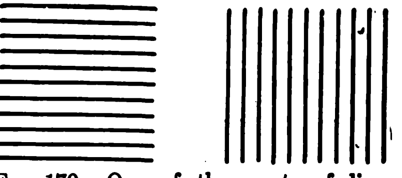


FIG. 170.—One of these sets of lines looks higher than it is wide. Is it? The other looks wider than it is high, Is it?

The poet was right when he said that things are not always what they seem. We are not always to believe our own eyes. There is always a little error in our sight. The examples present but a few of the many ways in which one's eyes may deceive him.

FIG. 171.—Turn the page round and round to the left. The plain rings will appear to revolve rapidly to the left, and the others to go slowly round in the opposite direction.

QUESTIONS

1. Why are lenses necessary for the near-sighted? The far-sighted?
2. State some conditions which should lead one to have his eyes tested.
3. How could one test for near-sightedness? For far-sightedness?
4. How test for astigmatism?
5. Why are people sometimes car-sick?
6. Tell some ways in which people often abuse their eyes?
7. What kind of lens corrects short-sightedness? Why?
8. What kind of lens corrects far-sightedness? Why?
9. What is the advantage of the meniscus lens over the flat lens?
10. What kind of light is best for the eyes when reading?
11. What kind of light should be avoided?
12. How should lamps be placed for general use?
13. Why does the room seem dark on coming in from outdoors?
14. Why have two eyes?
15. Why is the place where the optic nerve enters the eyeball called the blind spot?
16. Name some of the advantages of taking optical illusion into account when selecting a dress pattern.

ILLUMINATION

Method of Illumination.—Illumination should be, for general purposes, by diffused light rather than by direct; and by transmission or reflection or both. Glaring direct light is bad for the eyes. Not only does it lessen one's sense of comfort and repose, but it lessens whatever of charm there may be in the color scheme of one's surroundings.

Amount of Illumination.—One should not read in light which causes discomfort to the eyes. The high candle-power lights are greatly preferred, but only when so placed, or arranged, that the light is properly diffused.

The following table will give some idea as to the amount of brilliancy in candle-power per square inch of some of our methods of lighting.

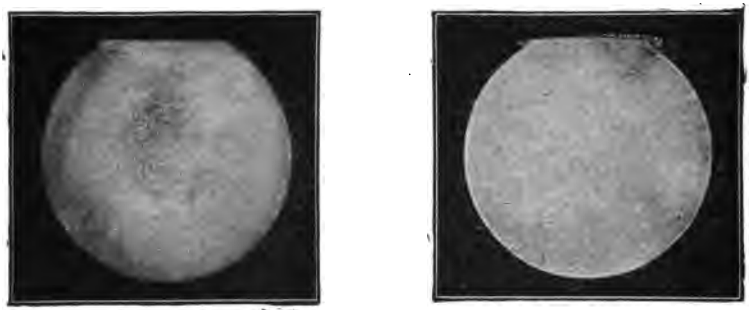
Source of Light.	Candle Power per Sq. In.
Candle	3 to 4
Oil Lamp	3 to 8
Gas Flame, Old Style	3 to 8
Welsbach Gas Mantle	20 to 50
Electric Light, Carbon Filament	375 to 400
Electric Light, Tungsten Filament	1000 to 1500
Electric Light, Nitrogen Lamp	15000 to 22000

Lights are measured by candle-power. As the words suggest, a light of a certain candle-power means the number of times more light that particular light gives than a candle. Standard candles are used for this purpose. To say a lamp has a candle-power marked sixteen (16) means that the light will give sixteen times as much light as a standard candle. It is customary to say that if a candle is placed one foot from a surface the amount of illumination received by it is equal to *one foot candle*. If the distance is increased the illumination decreases in proportion to the square of the distance.

Direct Lighting.—When the rays of light from a lamp are reflected in one general direction, usually downward, it is said to give *direct light.* This is accomplished by the use of a dense shade of glass, silk or metal. The usual type of reading lamp is an example of direct lighting.

Semi-direct Lighting.—Sometimes translucent reflectors which permit some of the rays to pass through upward, yet reflect the majority of the rays downward, are used. Reflectors of this type are examples of *semi-direct lighting.*

Indirect Lighting.—A light equipped with an opaque or partially opaque bowl reflector, the rays being directed upward to be reflected back by a white ceiling, is an example of *indirect lighting*. This type of light is by many considered the best, since it illuminates the entire room and relieves the eyes from all strain.



Ground glass globe. Opal Glass Globe.

FIG. 172.—Within each globe is a lamp of the same candle-power. Note the superior diffusion of the light by the opal globe.

Semi-indirect Lighting.—Translucent bowl reflectors which allow some of the light to pass through, but reflect most of it upward to be reflected back by the white ceiling, produce *semi-indirect lighting*.

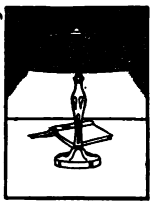


FIG. 173.—Direct light.

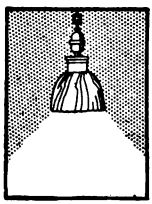


FIG. 174.—Semi-direct light.

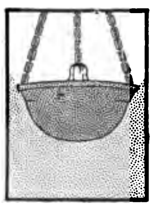


FIG. 175.—Indirect light.

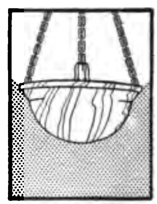


FIG. 176.—Semi-indirect light.

Light Transmitted through Various Colors.—The amount of light transmitted through colored glass is quite important if shades are used in the home. For ordinary illumination white or yellowish white, if diffused, is desirable. The yellowish tinge imparts softness, yet is cheery. Blue or green tinges impart a cold, hard aspect to objects in

general, and an unnatural pallor to the face. Strong deep red light is harsh, and is of so low visibility as to be impracticable.

Red lights have always been the danger signal on railroads, and elsewhere, although red is a poor color for the purpose. Green glass transmits more light than red, and would have been better for the danger signal.

Bust lighted in front from above. The same, lighted from directly overhead.

FIG. 177.—Bad lighting defeats good art.

Color of Walls.—The color of the walls of a room is an important matter. If the color is one that reflects light, instead of absorbing it, less illumination will be required and the cost of the lighting will be lessened.

It has been proved that a light buff tint is the most satisfactory color for the walls of a schoolroom. The space occupied in schoolrooms by blackboards causes much loss of light. Varnished woodwork and smooth wallpaper reflect more light, regardless of color, than a dull finish, or even the "satin" finish.

Questions

1. How should one sit with reference to the light when reading?

2. In what way are dark glasses of use when one is exposed to glaring light?

Fig. 178.—These two rooms receive the same light. Dark walls absorb most of the rays of light in the left-hand room.

3. Should seats be so arranged as to have the light come from the left side or from the right side? Why?

4. Why do rooms lighted by indirect light have few shadows?

5. In what part of a room in relation to the windows is it better for a teacher to stand when talking to her pupils.

6. Why is it difficult to see out of the window at night from a lighted room?

7. What kind of lights do you use in your home?

8. What warning has a person that the light is too bright?

9. What kind of lighting system is best for a home?
10. Why are red lights poor danger signals?
11. What kind of shades should be used for lights in halls?
12. What is the best kind of shade used in a home?
13. What happens when deep green and light blue are placed in a yellow light?
14. How much window space has your schoolroom, compared with the floor space?
15. What kind of light is best for studying?
16. Why is direct sunlight injurious for studying?
17. At what time of the day does direct light enter the room where you study?
18. At what part of the day do you have indirect light in your school room?
19. Why do some rooms appear darker than others with the same amount of light entering?
20. Why should rooms be well lighted with sunlight?
21. What causes the wavy appearance over a hot stove or over a sandy beach during a hot day?

COLOR

Color.—No object has color of its own but depends for color upon the light rays which are reflected by the material composing it. There is in the retina of the eye a set of nerves sensitive to red, another to green, and a third to blue light waves. When the rays from some object stimulate all three of these nerves equally the object looks white. If only the red nerves are stimulated, the object looks red; likewise blue or green when the blue or green set of nerves is stimulated. If one nerve is stimulated more than another, there is mixed color sensation and intermediate color effects.

The shade of these colors varies according to the amount of stimulation. Black objects absorb all the light rays. White objects reflect all light rays. If an object appears red, it has absorbed all the color rays except the red. Similarily the other colors.

The color of an object, then, depends upon reflection and absorption; i.e., upon which color rays are absorbed, which reflected. Color is a sensation, not the quality or property of an object.

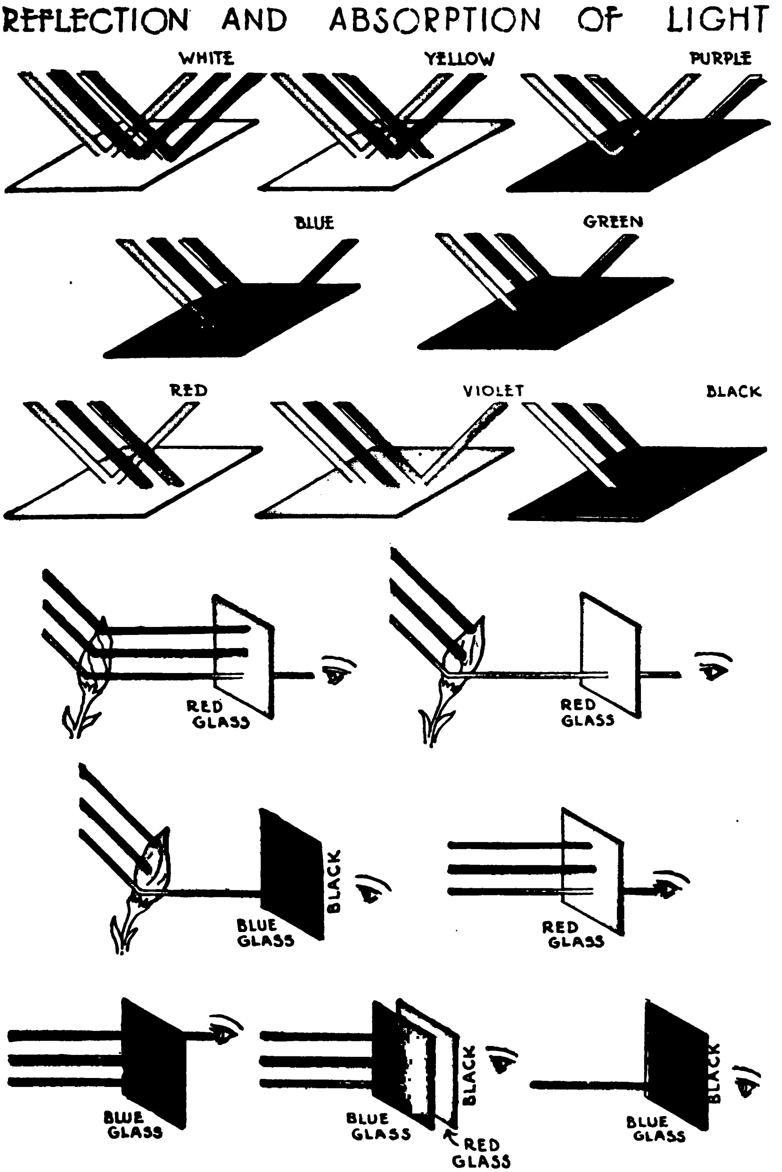


Fig. 179.—Study and apply the matter designated Fig. 179 on facing page.

Primary Colors.—There are three colors that are elemental, that is, colors which cannot be produced by combining any of the others. These three are yellow, red, and blue; they are the *primary colors*.

Binary Colors.—Yellow and red combined, make orange; yellow and blue make green; red and blue, violet. Orange, green, and violet are *binary colors* (*binary* meaning *made from two*).

Fig. 179.—As stated, color depends upon the light rays reflected and absorbed. When red, green and blue rays are reflected by any object, the object appears white (top row, at *left*). When red and green rays are reflected and blue is absorbed the object will look yellow (top row, at *middle*). What is the effect if red and blue are reflected and green is absorbed (top row, at *right*)? What causes a substance to look blue (2d row, at left)? What causes a book to appear green? (2d row, at right)? When will cloth look red (3d row)? When will paper look black? What color rays is a white rose reflecting? What color will a white rose look if viewed through a red glass? Why? What color ray is a red rose reflecting? What happens to the other two rays? Why does everything look blue through a blue glass? Why do things look black through a red and a blue glass? What happens when red objects are viewed through blue glasses?

Color Blindness.—Sometimes one of the sets of color nerves in the retina is lacking or much weakened. Railroad engineers must be tested to be sure that they do not lack the sense for red, since red is the danger signal. Men, as a rule, are affected more than women with color blindness.

Color Printing.—A knowledge of color combinations enables printers to produce many colors on one sheet or page, though printing the sheet only twice, or maybe three times, and each time with only one color of ink. Think out the way in which such results may be accomplished, interview a printer and report in class.

Questions

1. Powder together some yellow and blue crayon. Of what color is the mixture?
2. Do the same with red and yellow crayon. Color of the mixture?
3. Why is it preferable to select colored material by daylight?

For a perfect match, test by daylight and by artificial light.

4. Why do street lights, when viewed through a wire screen or a thin silk curtain. appear to have rays in four directions fringed with rainbow colors?

5. Why does a dewdrop on which the sun is shining change color when the position of the head of the observer changes?

6. Why is the sun red at rising and at setting?

7. Why is the foam of a muddy stream white?

8. In the peacock's tail, and on many butterflies of brilliant colors, there is no coloring matter. Explain this.

9. View the blue sky through yellow glass. What color does the sky seem? Why?

10. Why does blue cloth look nearly black in gas light?

11. Why is snow white?

12. Why is foam white?

13. Why is the ocean blue?

14. What part of this chapter is of greatest value to you? Why?

CHAPTER XI

ELECTRICITY

USE OF ELECTRICITY IN THE HOME

Measuring of Electricity.—The gas consumed in a home is measured in cubic feet. This gas burns and the products of combustion escape into the atmosphere. *Electricity*, however, is not consumed, but merely "flows" through the lamps, motors or other appliancess, and passes back to its source, the electrical generator. We do not, then, really use electricity, but use the energy which the moving electricity possesses. This energy is sufficient to produce light, heat or power by allowing it to flow through a lamp, a heating device, or a motor. The *amount* of electricity passing along the wires is counted in **amperes.** The *pressure* of the electricity is measured in **volts.** For example, "110-volt current" refers to the pressure by which the current is being forced over the wire. By multiplying the amperes by the volts we obtain a unit which expresses the rate of doing work, or the power, called **watts.** An appliance which requires a watt of energy would consume in one hour a **watthour** of energy.

The *commercial unit* for the measuring of electrical energy is called a **kilowatt hour,** which means 1000 **watthours.** For example, a 25-watt lamp will use 25 watt-hours in an hour, or the electrical energy supplied to the lamp in forty hours would equal 1 kilowatt hour (1000 watthours).

The Watthour Meter.—A watthour meter is essentially a small electrical motor driving a registering dial. All electricity which is used in the building must flow through this motor. If only one lamp is in use a small amount of current passes through. If two lamps are used, twice as much current passes through the meter.

The increase will be in amperes, since the volts remain constant. For example, if one light uses 1 ampere of current at 110 volts, two lights will use 2 amperes at 110

volts. The motor turns in the meter, thus registering the amount of energy delivered to the consumer.

Insulation.—Electricity functions over some substances much more easily than over other substances; for instance, electricity runs over copper wires easily, but not over or through rubber. A good conductor of electricity is some material which will carry the current. A poor conductor of electricity is something which will not carry the current, and which will prevent the current from getting by. Wires are covered

Fig. 180.—An instrument for measururing electrical pressure, volts.

Fig. 181.—Watthour meter.

with rubber, cloth, paper, etc., because those materials are poor conductors. Glass is used to support telegraph and telephone wires to keep the electricity from running off into the ground; and to support lightning rods to keep the electricity from running into the house.

MAGNETS AND MOTORS

Magnets.—There are two types of magnets; *permanent magnets* and *electro-magnets*. The word *magnet* came from an ancient city of Asia Minor near Magnesia where a black ore of iron was found. The ore is now found in various parts of the earth, and is called lodestone (leading stone), since it points to the North and South magnetic poles if suspended on a string. This ore strongly attracts iron and steel, and

also nickel and cobalt. A piece of steel may become a permanent magnet by stroking it with this mineral.

The electro-magnet is made by winding a piece of soft iron with wire, and running a current of electricity along the wire. Such magnets lose their magnetism almost as soon as the current of electricity is broken.

Magnets of this type are used in electric bells, telegraph instruments, induction coils, motors and dynamos.

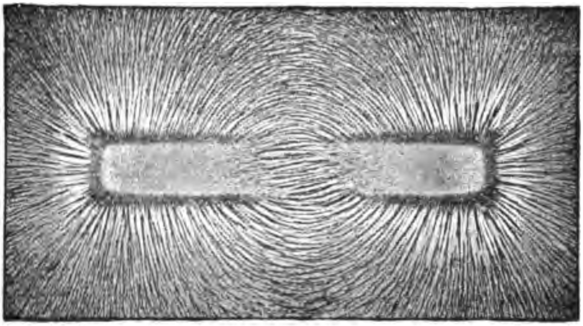


FIG. 182.—Iron filings on a paper placed over a bar magnet.

Experiments with Magnets.—Place a horseshoe magnet or bar magnet under a sheet of paper or glass. Shake iron filings evenly over the sheet with a salt shaker. Observe the force of magnetism, and the direction of the magnetic lines.

FIG. 183.—Put a bar magnet on top of some small tacks spread out on a table, and then lift it up. The tacks will cling to the magnet, but in unequal numbers at different parts. The magnet has *polarity;* that is, the places near the ends, where most tacks collect, are called *poles*.

Experiment with Electro-Magnet.—Wind a piece of soft iron with insulated copper wire. Attach the end of the wire to an electric battery. Bring the end of the magnet near tacks or other pieces of iron. Break the current of electricity. Observe what happens.

Law of Magnetic Attraction.—The point of the compass needle which is attracted toward the North magnetic pole is called the *plus* or North end, and the opposite end the *minus* or South end.

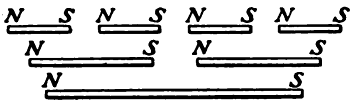


FIG. 184.—No matter into how many parts a magnet is broken, each part becomes a magnet with N and S poles.

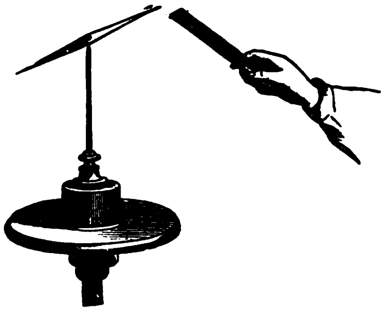


FIG. 185.—S attracts N. N repels N. What will S and S do?

Experiment.—Bring the North end of a magnetic bar near the North end of the compass needle. Bring the South end of the bar near the North end of the compass needle. Explain what happens. What does the law "*Like poles of magnets repel each other, and unlike poles attract each other,*" mean?

Motor.—The attraction and repulsion of magnets is made use of in the *electric motor*. The electric motor consists of a number of electro magnets fastened rigidly to a frame, and other magnets fastened to an axis, called an armature, on which there is a drum for brushes to allow the current to enter the motor.

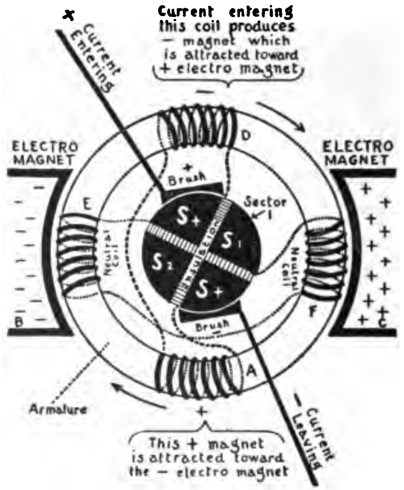


FIG. 186.—The Motor.

In Fig. 186 the electro-magnet A (+) is attracted by the minus (−) magnet B and repelled by the plus (+) magnet C; and the magnet D is attracted by the magnet C and repelled by the magnet B because the current is entering only the two coils F and E. Coils D and A have no magnetism in them, since the brushes do not

touch the sectors 1 and 2, called *commutators*, to which these magnets are attached. As soon as magnets *A* and *D* get to the places of magnets *E* and *F*, they lose their magnetism, and the magnets *E* and *F*, taking the places of *A* and *D*, become magnets and are likewise pulled in the same direction, causing the inner magnets on the axis to travel very rapidly.

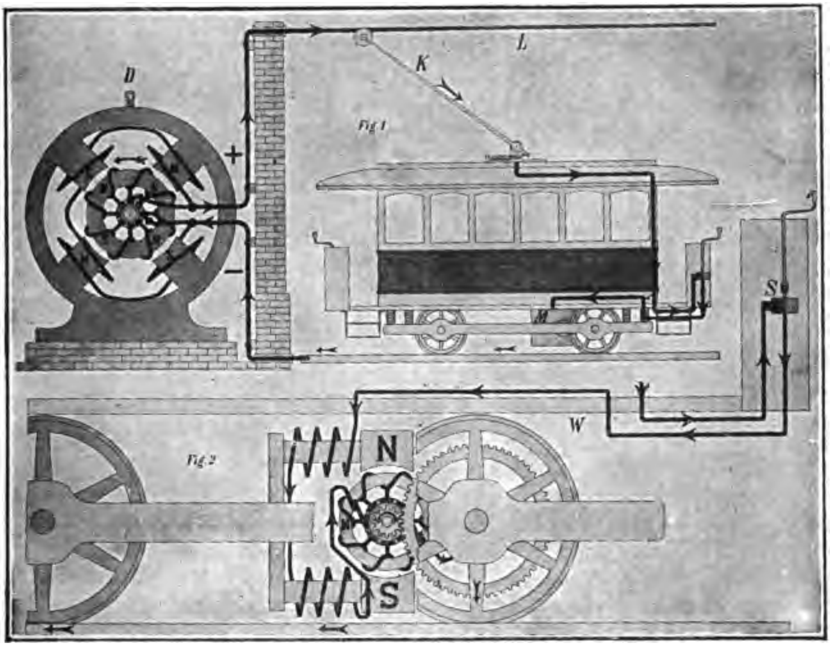


FIG. 187.—What is used for the return wire?

Commercial Motors.—The commercial motors used for the running of cars, automobiles, vacuum cleaners, fans, etc., supplied with a series of magnets which are alternately attracting and repelling each other. Not only do they have magnets at *B* and *C*, but these magnets are also wound with wire to produce very strong electro-magnets when the current is turned on.

QUESTIONS

1. Why not make the cores of electro-magnets of steel?

2. Why does the electric car move when the motorman "turns on the current"?

3. Why is it necessary to have electro-magnets in a motor?
4. How could a motor be made to run backward (reverse)?

GENERATION OF ELECTRICITY

Static Electricity.—Rub a hard *rubber* rod briskly with a piece of catskin. Hold it near two pith balls suspended by a silk thread. Try the rod on a bit of paper, cork, etc. Rub a rod of *glass* with a piece of silk or flannel. Bring this near the pith balls.

These experiments show that two kinds of electricity are generated. That generated by the *glass* rod rubbed with silk is called **positive**; that generated by the *rubber* rod rubbed with flannel is called **negative.**

If a body charged with negative electricity is brought near a body charged with plus electricity, the two bodies are attracted toward each other; but two bodies charged with the same kind of electricity repel each other.

Rub the barrel of your fountain pen on your coat and hold it near one pith ball which you have charged with plus electricity. What kind of electricity is the fountain pen charged with? Test a number of different materials rubbed with fur, catskin or flannel.

Potential.—If you hold a charged rod, rubbed with fur, near the finger you will feel a little prick and hear a sharp snap. A spark of electricity has passed from the rod to your finger. Also a charge passes from your finger to the rod, neutralizing the plus and minus charges. This exchange of electricity which takes place between two bodies is caused by the difference in potential or *pressure* of the electricity. We have already learned that the amount of the pressure of an electric current is measured in volts. This electricity contains no amperes of current; it is simply very high *voltage*. A spark 1 inch long has a voltage of about 75,000 volts.

Lightning.—Lightning is caused in much the same way. Electricity is carried from the earth while water is evaporating; and electricity is generated by the friction of clouds and wind.

Another theory, considered by some scientists to be more probable, is that electricity in the air is caused by minute particles called *electrons*, issuing from the sun in myriads, and bombarding the outer parts of the atmosphere.

When clouds are high above the earth, flashes of electricity will pass between them, but if a cloud is near the earth, the flash of electricity will pass between the cloud and some object on the earth. We commonly say the lightning strikes the object.

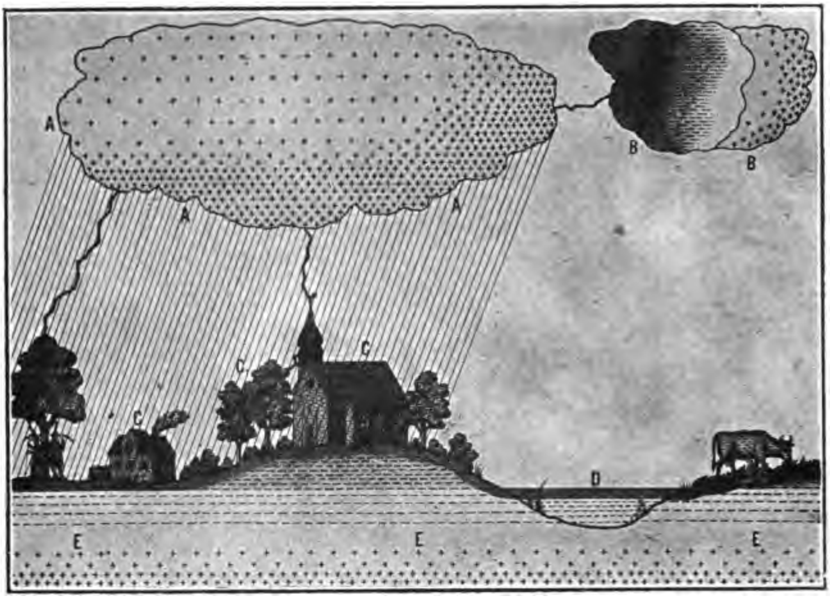


FIG. 188.—Thunderstorm. *E*, earth charged near the *surface* by *minus* electricity. Why? *A*, cloud charged with *plus* electricity; *C*, church, trees and house, charged with minus electricity. The man, the cow, the water, and all objects on the earth are charged with minus electricity during a thunderstorm. Why does the lightning "strike" the church or tree rather than the cow or ground? Why is the *interior* of the earth charged with *plus* electricity during a storm? Why is the left side of $B-$ and the right side $+$?

The most dangerous place in a thunderstorm is under a tree. Cattle are frequently killed in the pasture by the lightning striking the wire fence. Farmers should ground wire fences every few feet so as to allow the lightning to travel into the ground.

Lightning rods have been placed on buildings to protect them from lightning. The rod extends slightly above the highest point of the building, and runs down the side of the building into the moist earth. Buildings that are well protected by light-

ning rods are seldom "struck," since the current of electricity passes down the rods into the ground. Often, too, no spark is seen.

Thunderstorms.—Thunderstorms usually occur late in the afternoon or in the early evening of a hot sultry day. They are classed as traveling storms. Before the thunderstorm breaks, heavy masses of clouds are seen slowly rising and collecting near the horizon. The air which is very warm begins to be slightly cooler. Small detached clouds, forming in front of the large clouds, rapidly increase in size and unite with

FIG. 189.

the advancing storm cloud. Ragged squall clouds travel underneath the dark heavy clouds.

Some of the storms travel from twenty-five to fifty miles, carrying clouds of dust. At first large raindrops form which soon become smaller in size and greater in number until there is a heavy downpour. Occasionally hail attends thunderstorms.

QUESTIONS

1. Why does the hair sometimes snap when combed with a rubber comb?
2. Why are sparks seen if a cat's fur is rubbed in a dark room?
3. What kind of substances conduct electricity well?

4. Who invented the lightning rod?
5. Why are lightning rods pointed?
6. Why should the ends of lightning rods be deep in the ground?
7. Why may a man who is fixing a trolley wire touch the wire if he is wearing rubber shoes?
8. What is the third rail?

OTHER USES FOR ELECTRICITY

Ohms.—When electricity passes over a wire, if the wire becomes heated, that is due to the resistance the wire offers to the current. If a large amount of current is driven through a small wire, the wire becomes very hot because it offers much resistance. The amount of *resistance* is measured by **ohms.**

Wires for carrying a " heavy " current must be large to prevent them from becoming hot. The right sized wire must be placed in a house, or too much current running over the wire will cause the wire to set fire to the house.

Fuses.—Sometimes through short circuits (What are short circuits?) more current goes over the wire than should. If this excess of current continues to flow, the result may be disastrous. For this reason, fuses are used. These are made of some metal which melts at a low temperature and are pieced into the wire or other conductor. When the current becomes too "strong" the heat melts the metal of the fuse, which "blows out," severing the connection, and "breaking" the current of electricity, thus preventing damage.

Electric Heaters.—Electric stoves, heaters in cars, electric bed warmers, electric flatirons, etc., all work on the principle of getting small wires very hot as a result of resistance.

Electric Incandescent Lamps.—The carbon and Tungsten lamps contain small wires which offer great resistance to electric currents. They become white hot, because of their resistance to the electric current, giving us light for our homes.

Amount of Resistance Required.—We have already mentioned that the amount of current which can get over a wire depends upon the amount of resistance, **ohms of resistance,** the wire offers to the current. It also depends upon the pressure **volts** with which the current is being

driven over the wire. The harder the current is "pushed" or driven over the wire the hotter the wire becomes.

QUESTIONS

1. Why is it necessary for the "film" in electric light bulbs to have high resistance?
2. Why have fuses in or in connection with electric light appliances?
3. Why is bell wire unsafe to use on electrical appliances which are attached to the supply current?
4. Why does great resistance reduce the cost of operation?

USES OF CELLS AND MAGNETS

Electric Bell.—Examine the electric bell.

What are the magnets *H* and *I* called?

G N is a piece of soft iron.

Why is *GN* pulled to the magnets *H* and *I* when a current of electricity enters the wire around the magnets?

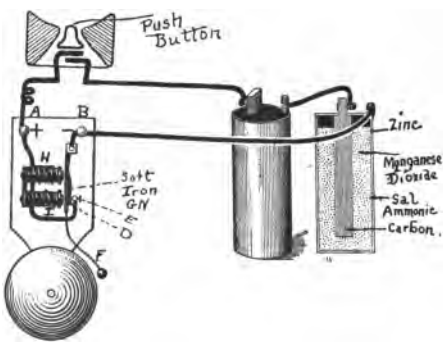


FIG. 190.

The current enters the bell at *A* and leaves at *B*.

Why does the hammer *F* hit the bell when the current is turned on?
What happens at *D* and *E* when *GN* is pulled toward the magnet?
When the current is broken, what happens to the magnets *H* and *I*?

As soon as *I* and *H* lose their magnetism, *G N* spring back, causing *D* and *E* to meet again.

Why do *G* and *H* become magnets again?
How quickly do you think *G* and *H* become magnets, and lose their magnetism?
What is the push button for?

Telegraph Instruments.—Telegraph instruments have electro-magnets which cause a little bar of metal to be drawn to the magnets. Examine a telegraph instrument.

What causes the "tick"?

The key acts as the push button, turning on the current through the magnet. According as each pressure upon the button by the

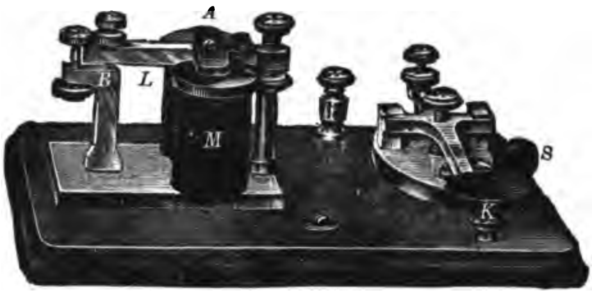


FIG. 191.—Telegraph instrument. Why is *A* a soft piece of iron? Why is *M* an electro-magnet?

sender is brief or prolonged, the record made by the receiver's instrument is brief or prolonged, i. e., a dot or a dash. Many of these instruments are connected in series in different towns, and messages are spelled out by means of agreed-upon arrangments of the dots and dashes.

Cells.—An electric cell may be made by so placing pieces of zinc and copper, called an **electrode,** in dilute sulphuric acid that the two pieces of metal do not touch each other. If a wire is used to connect them outside the acid an electric current will flow from the copper (+) to the zinc (−) on the wire.

From what and to what does the current flow inside the battery?

Wet Cells.—The most common wet cell used is one made from sal-ammoniac (ammonium chloride) dissolved in water. Zinc and carbon are used for the electrodes. The current flows from the carbon to the zinc on the wire outside the battery.

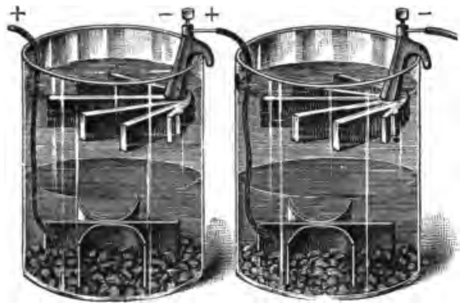


Fig. 192.—Two wet batteries attached in series.

Dry Cells.—The "dry cell" is made up of a zinc jar in which are packed damp sal-ammoniac, zinc oxide and zinc chloride. Pitch is placed over the top of the materials to prevent the water from evaporating. A piece of carbon is placed in the center of the cell from which the current flows. Manganese surrounds the carbon at the center of the cell.

Open an old dry cell and examine the structure.

Parallel and Series.—Batteries, lights and many electrical instruments are wired *in parallel* or *in series*, according to the requirements

Batteries are wired in parallel by running wire from the *zinc* to the *zinc*, and from the *carbon* to the *carbon*, thence to the instrument.

Batteries are wired in series from *carbon* to *zinc*.

The result of parallel connection in batteries is to produce a large number of amperes and the voltage equal to one cell. Electroplating work requires such conditions.

Electric lights for our homes are wired in parallels since the lights must be turned on independently of each other.

Where two or more electric bells are operated from the same push button they should be wired in parallel.

Whenever we wire batteries to door bells we need as much voltage as possible to drive the current over the wires, for they may be 100 feet or more in length.

Storage Cell.—The storage cell is used in automobiles, in homes and in schools for many purposes requiring the use of electricity. These cells must be charged.

The electricity does not really go into the cell and stay there but stores up its *energy* in the cell. This energy once stored up is a source of current in the opposite direction from which the current passed into it.

Project.—Find out how storage cells are made; the different places where they are used; how they are charged; when we know they are fully charged, and what the cell contains.

A Battery.—A battery is a number of cells united in series or parallel. Sometimes a single cell is called a battery. This, of course, is an incorrect use of the word.

Questions

1. Why is the voltage marked on the lights (bulbs) in your home?
2. What would be the effect of placing a lamp marked 110 volts on a current which had a pressure of 220 volts?
3. Why are flatirons, vacuum cleaners, etc., marked with both amperes and volts?
4. What causes the telegraph instrument to tick when one presses the key?
5. Why are "dry cells" called dry cells?
6. Why are lights in a home wired in parallels?
7. What would be the effect if the lights were wired in series and one light went out?

CHAPTER XII

THE RELATION TO US OF SOUND AND MUSIC

SOUND

Sound Waves.—We have learned that light comes to us from the sun and stars through the *ether*, in a series of waves which, when they enter the eye, affect the optic nerve. and are called light waves. Waves which are produced in the *atmosphere* we call *sound waves*. They affect the auditory nerve of the ear. As sound is the result produced by the waves striking the ear drum and sending a sensation along the auditory nerve to the brain, sound is really in the brain.

The waves themselves do not make a noise. There are only so many sounds in a place as there are ears to receive the sound waves or vibrations. If one should strike a blow near the end of his finger extended in front of him there would be no sound at the end of his finger. Sound waves, however, besides beating against the finger might pass on until they reach some body which is capable of receiving the sound waves upon the sort of tissue that will send the sensation along the auditory nerve to the brain, and " be heard " there as " sound."

Sound waves move out in a straight line from their source, not like the waves of a pond, but in a backward and forward motion, similar to that when one billiard ball hits another, forcing ahead the one that is hit. If the second ball hits a third, the third is pushed forward, and so on.

Sources of Sound Waves.—Sound waves issue from vibrating bodies. Something must move in order to set the air in motion.

Some bodies vibrate so *rapidly* that they send off a series of sound waves which hit the ear drum with a rapidity too great for the auditory nerve to receive and form into sensations of sound. In other words some sound waves have no audible effect. On the other hand, if a body vibrates *fewer* times than sixteen times per second, the resulting sound waves will have no audible effect.

Sound Waves and the Human Ear.—Appliances have been devised and employed for determining the rate of the vibrations that go with sounds of many kinds and degree. Here are some of the results:

16 vibrations per second:—The lowest audible sound.
32 vibrations per second:—The lowest musical sound.
128 vibrations per second:—Man's conversational voice.
512 vibrations per second:—Woman's conversational voice.
2,000 vibrations per second:—High soprano.
4,000 vibrations per second:—Highest musical tones.
40,000 vibrations per second:—Highest audible sound.

The Ear.—Sound waves enter the ear, which has the right shape and character for the functions it performs. Waves strike against the thin

FIG. 193*a*.—This diagram shows the inside of the ear, from the entrance to the end of the nerves of hearing that pass to the brain. The drum stretches across the end of the canal, and on the other side is the chamber of the middle ear, filled with air that enters from the throat. In this chamber are three small bones, the hammer, the anvil, and the stirrup, the last being fixed to the drum of the inner ear which is shaped like the coils of a snail's shell.

membrane called the drum of the ear, also called the **tympanic membrane.** To this membrane are attached three little bones, **the hammer, the anvil** and **the stirrup,** which assist in transmitting the vibrations produced by the sound waves through the middle ear to the *spiral*

(snail-like) *canal*, also called the **cochlea**. The cochlea is filled with a liquid in which are stretched more than ten thousand filaments of the auditory nerve. These filaments vibrate sympathetically with the sound waves, to transmit a sensation to the auditory nerve, and thence to the brain.

If the number of vibrations of the sound waves is less than 16 per second, these do not carry them on, and no sound is heard; likewise if the sound vibrations are more than 40,000 per second.

It is believed by some that many insects produce sound waves with too high a number of vibrations or too low a number of vibrations to be transmitted into sound and heard by human beings.

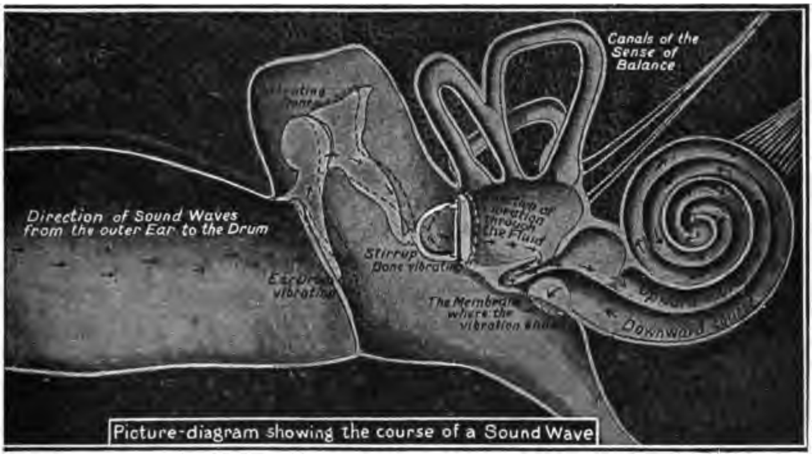


Fig. 193*b*.—Here is pictured a sound-wave striking the ear drum. The effect is to move the handle of the hammer which pulls the anvil, and that pushes the stirrup (shown by dotted lines) against the drum of the inner ear. Tiny waves of the fluid inside this inner ear cause vibrations through a membrane which lines the shell, and traveling round the coils in the direction of the arrows, communicate the sensation to the nerve.

Courtesy of Child's Book of Knowledge.

Echo.—When sound waves are stopped by any object and sent back, an **echo** is produced; that is, the sound may be heard again, as if called back from a distance. If the sound waves are broken, so as to become irregular, they do not come back as an echo.

The ancients believed that the echo was produced by a nymph, Echo, a daughter of Air and Earth. The story goes that Echo at one time could talk like other people. Jupiter employed her to talk to his wife Juno and keep her so busy she would be unable to watch him. When Juno discovered this she punished Echo by condemning her to repeat the last few syllables of any word or sentence spoken in her presence.

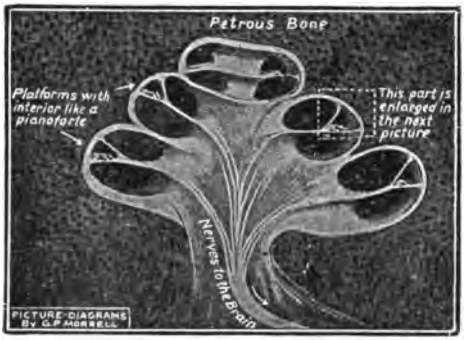


FIG. 193c.—In this picture the spiral coil (cochlea) is cut through from top to bottom. The galleries are filled with fluid, and contain marvelous organs. The part in the dotted square is shown, enlarged, in the next picture.

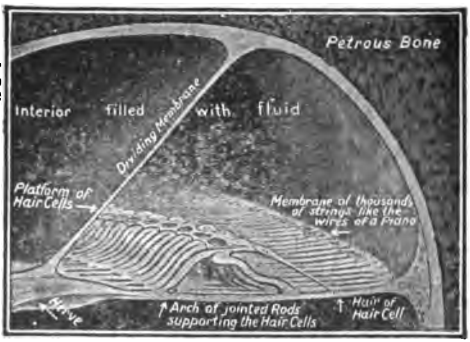


FIG. 193d.—Over 3000 little hammers, jointed like those of a piano, support thousands of hair-cells that rest on a membrane. More than 10,000 strings are stretched across like piano wires, and these convey the wave sensations to the nerves of hearing going to the brain.

If you stand in front of a cliff or abrupt hill and shout or sing, the sound or sounds will be repeated. The sound waves strike the cliff and

are reflected, repeating to you the sounds. At a place in Woodstock, England, a fine echo repeats as many as 14 syllables.

Water is a good reflector of sound. People in balloons can easily hear sound reflected from water. Clouds will reflect sound. This is shown by firing a cannon. If the sky is clear a large gun produces a sharp report, but if there are clouds in the sky the report of the gun will be heard as an echo similar to thunder "rolling." In fact, the rolling sound of thunder is due to the sound waves rebounding from the clouds—virtually a series of echoes.

Whispering galleries are examples of sound waves rebounding from some point where they have concentrated, usually in a concave surface. Many of the rotundas of the state capital buildings in the United States are examples of whispering galleries, but one must stand in the place where the sound waves are reflected to a point, or focus.

Sound Waves in a Room.—In some auditoriums the listeners may have difficulty in hearing the speaker. We have learned that sound waves proceed in straight lines; but they may be obstructed by draperies, screens, etc. Ventilating flues, hot-air registers, steam radiators, by their air currents, may interfere with sound waves. Hot air rising from footlights in front of a speaker render his words less audible. Frequently singers prolonging a note seem to have an uneven tone; the sound waves have to pass through the currents of warm air which rise from the floor between the singer and the listeners.

Sound waves die on soft or dead surfaces such as carpets, curtains and drapery. Velvet is the best material for exhausting sound waves.

Metal mirrors and polished plate glass reflect sound waves.

Speed of Sound.—We are all familiar with the fact that we do not hear the thunder as soon as we see a flash of lightning. This is because sound does not travel as fast as light. Sound travels 1088 feet per second in dry air at 32° F. (0° C.), and the speed increases a little over 1 foot for every degree of rise in temperature F. (2 ft. for each degree C.).

Beats.—Sound waves producing two unlike tones cause **beats** or places where one wave may virtually annihilate another, resulting in silence. This produces a wavy or throbbing sensation. The ding-dong of a bell and the tremolo are good examples.

Noise, Sound and Tone.—Any instrument which will cause the air to vibrate will produce noise, sound or tone. *Noise* may mean sound in general, but usually means that confusion of sounds which is the result

of **irregular vibrations** of the air, and is disagreeable. By sound, i. e., *a sound*, is usually meant the result of **regular vibrations** of the air. *Tone* is a sound thought of as having a musical quality or (tone of voice) as expressing some feeling. To be recognized as a tone a sound must have a vibration number not lower than 16. The tone C, for example, in music, has 256 vibrations per second.

Questions

1. If a book fell off the table and there were no beings within range of the resulting air vibrations would there be a "noise"? Explain.
2. What causes the "snap" of a whip?
3. What causes the noise made by clapping your hands?
4. Why does not waving the arms produce a noise?
5. How far away is the lightning whose thunder is heard 15 seconds after the flash, on a summer's day (temperature 80° F.)?
6. Should there be a sound from a bell in a vacuum? Explain.
7 Why does a bullet or shell whistle?
8. Does the same explanation account for the whistling of the wind?
9. Why do telegraph wires hum?
10. Why does one hear better through the small end of a megaphone?

MUSIC, AND SOUND INSTRUMENTS

Resonance.—Blow a whistle across the mouth of a large bottle, gradually raising the pitch until the tone is sounded, which will cause sympathetic vibrations in the air within the bottle, thus prolonging or reenforcing the sound waves of the whistle. That characteristic of a substance or object by which it is capable of prolonging or reenforcing a sound through sympathetic vibrations, is called **resonance.** The prolonged or reenforced sound itself is also called resonance.

Hold a vibrating tuning fork over a tall cylindrical jar, slowly adding water until the sound waves given off by the fork are reenforced. A high degree of resonance is obtained.

Sometimes a fly or a bee placed in a bottle of the right size gives a good example of resonance.

Sympathetic Resonance.—If a slide trombone is sounded in front of a pipe organ, a pipe which will produce the same type of tone will respond sympathetically. If the trombone is sounded progressively from a low pitch to a high pitch the different pipes will respond, each to its own tone, and pipes which cannot produce the vibrations of the tone will remain silent.

This is also true of the strings of a piano. If a person sings in front of a piano, the string which has the same musical pitch as the sound will vibrate, producing a sound of its own.

Experiments; Sympathetic Resonance:

1. Fasten two steel wires securely on a bridge at one end of a long ooard. Into the other end of the board insert two screws about two inches apart. Fasten the wires to these screws and tighten the wires by turning the screws until they produce the same pitch. (Such an instrument is called a **sonometer.**) Place on one string a piece of paper folded into a V shape, called a **rider**. Set the other string vibrating. If the two strings are tuned exactly alike, the string with the rider on it will soon be seen to vibrate sympathetically.
2. Stand in an empty room and produce a sound, gradually changing the pitch until the correct pitch is heard. The empty room will then seem full of sound. All corners, angles, and pockets will respond when the proper pitch is struck. If the room is round or has a spherical ceiling, a great deal of sound will be obtained.
3. Release the loud pedal on the piano and strike the key C. Immediately place a finger on the strings of C which are vibrating and listen to the sympathetic tones produced.
4. If two tuning forks of the same pitch be placed at the right distance apart, and one fork caused to vibrate and then suddenly to stop, the other fork will be heard producing a sympathetic tone.

Sympathetic Noise.—A piece of metal may be caused to rattle by the playing of some note on the piano or other instrument; teaspoons in a glass holder or in a pan may rattle.

Sympathetic Vibration of Tuning Forks.—If two tuning forks, fastened to resonance boxes as shown in the illustration, are placed at the proper distance apart, and sounded, the sound waves will vibrate in perfect unison, and the sound produced will be twice as loud as that produced by one fork. If the forks be placed at such a distance that the sound waves of one are not in unison with those of the other, the vibrations will interfere in such a way as to quench the sound, and the result will be silence

Singers may have difficulty in striking a familiar pitch because some instrument, or wall or pocket, in the room has a resonance to which the singer responds sympathetically, pitching the voice lower than was intended. A slight change in position may remedy this trouble.

FIG. 194.—If one fork is struck the other will begin producing a tone in sympathy with the first.

Sounding Board.—Most stringed instruments are placed upon some type of board to cause the air to vibrate, usually on a hollow box called a resonance box or sounding board. The piano has a sounding board over which the strings are stretched. The vibrations of the strings are transmitted through the frame to the sounding board, which then vibrates sympathetically.

The sounding board is so much larger than the strings that it causes a greater expanse of air to vibrate than the strings alone could, and with a better resonance.

Simple and Compound Tones.—*Simple tones* are produced by a body vibrating as a whole; *compound tones* by a body vibrating as a whole and also in parts at the same time.

Fundamentals; Overtones.—Briefly, all tones are divided into groups of tones, each having its own number of vibrations. The various tones are called **partial tones,** and of the partial tones the one having the lowest number of vibrations is called the **fundamental,** while the others are called the **overtones.** As a rule, the fundamental predominates, but

with bells the overtones predominate. If the overtones have vibrations which are exact multiples of the fundamental, they are called **harmonics.**

In Fig. 195 a record is shown of sound waves caused by a tuning fork vibrating as a whole, producing a fundamental.

Piano strings not only vibrate as a whole, but in parts.

A heavy bass piano string about 10 feet in length may be obtained from the American Steel and Wire Company. With this may be shown the vibrations of a piano string and its fundamentals and overtones plainly enough to be easily visible. By stretching it from one nail to another, drawing it tighter and tighter while plucking it, the proper tautness will presently be apparent.

FIG. 195.—Tuning fork. The tone of a scientifically mounted tuning fork has no partial-tones. Its tone-wave is free from the irregularities present in other tone-waves and caused by their partial-waves.

FIG. 196.—Violin. Indicating many partial-tones, not aggressively dominant; hence the fluent, smooth, quality of the instrument. This is shown in the photograph of its tone-wave. There are many irregularities in the wave, but they are all too small to influence its general symmetry.

FIG. 197.—Oboe. A tone-wave of distinct individuality. The pronounced irregularities exhibit the dominance of certain of its partial tones.

FIG. 198.—Human voice. A record of the tone-wave created by pronouncing the vowel sound "ah." The human voice is rich in partial-tones, some voices, indeed, containing as many as 40 that are distinguishable.

Fig. 196 shows the string of a violin vibrating as a whole, and in many parts at the same time.

The vibration of any whole string produces the fundamental tone which determines the **pitch**. The many little vibrations of a string produce tones above the fun-

damental which are called **partials or overtones.** Fig. 197 records sounds produced by vibrations as a whole and in many parts. The partials or overtones give tone quality and richness.

Tones from String Instruments.—String instruments depend for their tones upon the size, the length, and the tension (degree of tautness) of the strings.

Fig. 199.—The modern harp. According to the Bible the original harp was invented by Tubal. The harp is said to be the most ancient of stringed musical instruments. Certainly, few have been more charming among instruments played with the fingers.

For example, the strings of a piano which produce the bass notes are large and long, while those which produce the high tones are short and of smaller diameter. The tone is maintained by keeping the strings at a certain tension or tautness.

Experiment.—Notice the effect of *tightening* the string on a sonometer (page 248), also the effect of *shortening* the string; and, if possible, the effect of same upon two strings of different diameters having the same tension. This last may be accomplished by attaching two strings about 2 in. apart to the board and allowing one end of the string to run over a bridge on the edge of the table instead of using the screws for tightening at that end. Attach weights of the same avoirdupois to both strings.

Human Voice.—The human voice is produced by an apparatus located at the top of the trachea comparable to a reed musical instru-

ment. The place is marked by the Adam's apple. Thin projecting membranes called *vocal cords* are situated on each side of a slit. These are limp or relaxed when inactive, as when a person is merely breathing; but when one wishes to speak, muscular action takes place in the vocal cords, bringing them close together so that the air from the lungs when forced against them causes them to vibrate.

The pitch of the voice depends upon the muscular tension (degree of tautness) of the cords, while the intensity depends upon the force of air and the position of the mouth and throat and the varying shapes of the cavity as altered by the changing shapes or attitudes of the vocal cords and adjacent parts. The mouth, throat, and nose act as resonant box cavities which, by automatic changes in form and size, cause different qualities of tone.

Piano Player.—Piano-player action depends upon the atmospheric pressure. The familiar piano hammers are made to strike the strings by means of suction. The perforated paper roll passes across the tracker-bar, which has a row of small holes each one of which is connected by a slender rubber tube to the hammer of a key—each hammer having its own rubber tube leading to its own perforation in the paper music roll. When a perforation in the paper passes over an opening the air rushes in, causing air pressure on the hammer to strike the proper string. The perforations in the paper roll are so arranged as to correspond exactly with the notes of the music to be played. The air pressure is produced by means of suction bellows worked either by foot pedals, or by electric motor (in some players by both, at will).

Phonograph.—If a person sings into, or any sound is projected into the large end of a horn the sound-waves will be collected at the small end. If a diaphragm with needle properly attached is placed at the small end of the horn, the collected sound-waves will make the diaphragm vibrate, causing the needle also to vibrate and cut grooves in any impressible surface having contact with the needle point. Let the impressible surface be kept moving along at a uniform speed, and the sound-waves will be progressively recorded.

Now, if a needle, properly attached to a diaphragm, is kept in one of those grooves while the groove is made to move along at (preferably) the original uniform speed a sound will be produced quite like the sound which was projected into the horn.

As the impressible material is presumably too soft to retain

grooves in their exact shape against the friction of the needle point, a durable hard surface must be provided. One method is to "copper-plate" the grooved material; remove the copper plate, which will have all the grooves recorded on it as ridges; and then use this copper plate in a process of stamping the grooves into soft discs of a material which, when hardened, will be the familiar phonograph records.

Telephone.—Sound waves striking a thin membrane, or a diaphragm, cause it to vibrate.

This principle obtains in the human ear. The ear drum is a thin membrane which vibrates when sound waves strike it, sending vibrations through the auditory nerve.

Alexander Graham Bell got his idea of the telephone from the ear drum. He conceived it possible for a diaphragm to be made to vibrate by sound-waves; and for this vibrating diaphragm to be so connected with the end of a wire as to cause electrical currents to move along it to its other end and make another diaphragm there vibrate in exact unison, producing sounds imitating the original sounds at the beginning of the process.

The telephone is made on this principle. That is, a solid metallic diaphragm (receiver) receives the vibrations of the voice; these vibrations are carried, by means of electricity, along a wire, and are reproduced exactly in another diaphragm at the other end of the wire.

Of course the sound itself does not go from speaker to listener. It is the electrical "currents" which "flow" along the wire, and at the other end set up the vibrations in the diaphragm there. A part of the apparatus at each end is a magnet in front of the diaphragm similar to the magnet learned about in the last chapter.

If the sound waves themselves should travel from New York, say, to San Francisco a person at San Francisco would not hear the New York speaker's voice until four or five hours after he had spoken. But the time in which electricity will actually "carry" the voice from New York to San Francisco is $\frac{1}{15}$ of a second.

Visit your local "central" and have the workings of the sytem explained to you.

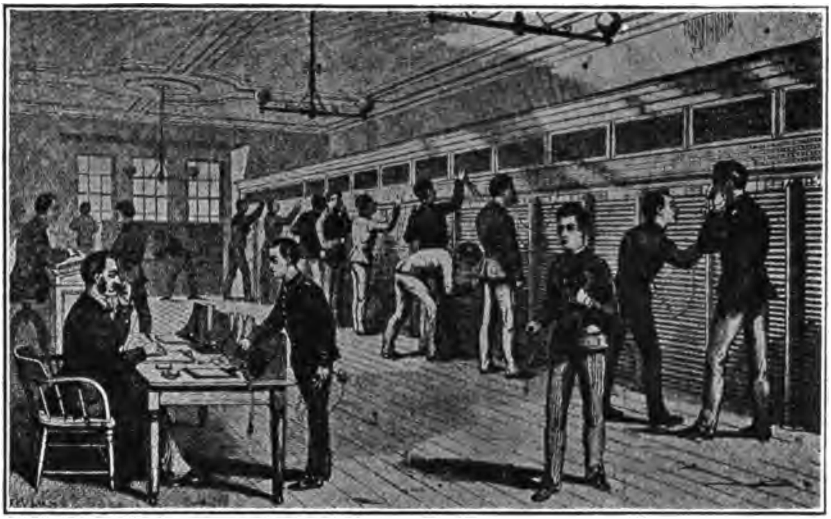


FIG. 200.—An early telephone exchange. When telephone exchanges first appeared boys were employed to make connections.

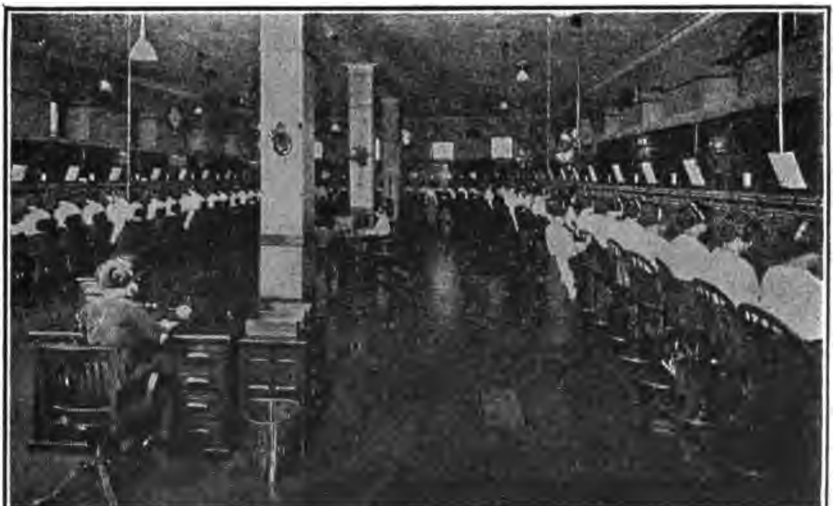


FIG. 201.—The modern telephone exchange. Why do you think girls were substituted for boys?

CORRECT TELEPHONE HABITS

On All Outgoing Calls

Look in the telephone book to **make sure** that you call the **right** number. If you do not find the number in the book ask "Information."

Call **this number** with a slight pause between the hundreds and the tens. For example, in calling "Barclay 1263," say, "Barclay One Two (pause) Six Three.

Speak **clearly** and **distinctly,** directly **into** the transmitter.

Listen to the operator's repetition of the number and acknowledge it.

Hold the line until your party answers, and then give your whole attention to the telephone conversation.

To recall the operator, move the receiver hook up and down **slowly.**

When you have finished talking, say "Good-bye" and replace the receiver on the hook.

Courtesy at the telephone is worth while. It wins friends.

On All Incoming Calls

Respond **promptly** and **pleasantly** to the telephone ring.

Announce your name. Don't say "Hello."

Be ready with pad and pencil so as not to delay your caller.

Listen attentively so as not to have to ask the caller to repeat.

Maintain the same courtesy and consideration in a telephone conversation that you would in the person's presence.

"*The voice with the smile wins.*"

Questions

1. Why does a listener hear better if the speaker uses his hands as a trumpet?
2. Why does a dog prick up his ears when he hears a sound?
3. Of what advantage is it for a person to place his hand behind his ear when trying to hear a faint sound?
4. Of what use is the horn on a graphophone?
5. Why do announcers often use a megaphone?

6. How does the violinist tune his violin?
7. How does he produce high and low pitches on the same string?
8. Why does a violin have a hollow box under the strings?
9. Why is there an opening in the box?

FIG. 202.—Violin. How are high and low tones produced on the violin?

10. Why does a string over a sounding board cause a louder tone than a string vibrating alone?

11. Why never leave the telephone receiver off the hook?

12. Why is it unfair to use the telephone for a long talk about unimportant things?

13. Who is usually more courteous over the telephone, you or "central"?

14. What parts of this chapter are the most useful to you?

CHAPTER XIII

THE UNIVERSE

LAWS OF MATTER

Molecules.—All material substance is believed to be composed of particles so minute as to be no longer *physically* divisible. The smallest particle into which a substance may be conceived to be divided and yet retain the essential characteristics of the substance is called a **molecule.** For example, the smallest particle of water, *as water*, is a molecule of water. So small is every molecule, of whatever substance, that no one has been able to see one, even with the strongest microscope.

Lord Kelvin, the British scientist, to illustrate how minute he conceived the molecule to be, said that if a drop of water were magnified to the size of the earth, the water molecules, proportionately enlarged, would be even then no larger than between the size of small shot and cricket balls.

When a teaspoonful of sugar is stirred into a cupful of water the sugar disappears from view. The sugar-grains are believed to break up into their molecules and be distributed throughout the water—too small to be visible, yet obviously retaining, for example, one characteristic of sugar, the sweet savor; proved by the sweetness of the water now containing it.

In support of this belief regarding molecules there are many other evidences in the phenomena of nature. Yet, though based on innumerable observed facts, this belief has not been absolutely confirmed. So we are content to call it a good working *theory*. Let us call it the **molecular theory.**

All molecules, particularly those composing any given substance, attract one another strongly. That is why the sugar, say, naturally stays sugar. This attraction is comparable to gravitation, by which, as we shall learn later in this chapter, all bodies in space are affected. If the substance is a liquid and unhampered, the molecules, every one drawing and being drawn by the others, tend to take on a spherical shape. A mere drop of water is an example.

Atoms.—The molecules themselves are believed to be composed of still minuter particles. The accepted name for these is *atoms*. The atoms, too, are believed to be still further divisible. The theory by which the scientists explain the existence of the atoms and their supposed qualities and activities is called the **atomic theory.** These activities are assumed to embrace the ways in which atoms combine into molecules, the ways in which they separate from them, their arrangement when in the molecules, their status and their motions in relation to one another, etc., etc.

Cohesion.—Experiment. *Carefully* place a dry needle level on the surface of some still water. It will float.

Every molecule of water is pulling every adjoining molecule with a considerable force (the molecular attraction), but the upper surface of the top layer of the water molecules adjoins, *not* water molecules, but air molecules whose pull is weaker than the pull of water molecules. The effect is to make the surface of the water more tense; indeed, the scientists use the term *surface tension* to designate the condition; it is a kind of *cohesion*. The needle will not sink until the surface tension is in some way diminished or counteracted. We call **cohesion** the molecular attraction when holding together the molecules of the substance or body of which they are a part.

Cohesion is important to our life. Pieces of wood stick together because the molecules of the wood *cohere*, and the stronger the cohesion the harder it is to break up the body. The distance between the molecules before cohesion can become effective must be, so it is said, within a millionth of an inch.

Adhesion.—It is often practicable to use glue or cement to mend a piece of wood or china which has been broken. Sometimes the molecules of one kind of substance are attracted with a great deal of force toward the molecules of a different kind of substance.

The glue molecules have a greater attraction for the wood molecules than the wood molecules at the surface of one piece of wood have for the surface molecules of the other piece of wood. Likewise as to the attraction of glue molecules for china molecules, compared with the attraction of china for china.

For this reason, two pieces of wood or china which must be mended are treated with the glue and then tightly pressed together to get the molecules of glue and the molecules of the wood or china into the close -t necessary. This kind of cohesion is called **adhesion.**

Capillarity.—Immerse (upright) in water one end of a clean fine-bore glass tube, open at both ends. See the water within the tube rise to a higher level than the water without; also the higher level of the *edges* of the water column next the glass sides of the bore. It is as if the water climbed up the bore, and then the particles next the glass tried to climb higher. If you try tubes with bore of different size, the finer the bore the greater the height of the water. These are *capillary phenomena.* (Look up the word capillary in the unabridged dictionary, and report.) Such action of a liquid toward a solid, and the properties of liquids and solids which cause them to act thus toward each other are spoken of as **capillarity**. The underlying action is adhesion.

Capillarity is illustrated when a corner of a sugar-lump being touched to the surface of a "cup of coffee," the coffee quickly colors the whole lump. Barely touch the corner of a piece of clean white blotting paper to the surface of a drop of ink on a piece of glass, and tell what happens, and explain.

Indestructibility.—The *atoms* which make up molecules cannot be destroyed. We may manufacture paper from wood but the atoms which make up the molecules of wood will not be destroyed. We will have rearranged them, producing a different substance. If the paper is burned the atoms will not have been destroyed. Some have passed off in smoke, others remain as ashes, but whatever they were in the original wood, atoms of hydrogen, atoms of oxygen, or atoms of carbon, they are still atoms of hydrogen, oxygen or carbon though gone into the making of new substances. That property of atoms, because of which they cannot be destroyed, is called **indestructibility.**

Other Properties of Matter.—Matter has several other familiar properties.

Porosity.—One is **porosity**, which permits the spaces between the molecules of one substance to be entered by the molecules of another but different kind of substance. The molecules of salt and sugar are capable of getting into the spaces between the molecules of water.

Ductility.—A property of matter which allows certain types of material to be drawn out. For example, copper, steel, and some other substances may be drawn out to form wire.

Malleability.—A property of matter which permits substances to be pounded into thin sheets. For example, gold is very malleable; it may be pounded into a sheet as thin as $\frac{1}{300000}$ of an inch thick.

Tenacity.—A property of matter which prevents bodies from being easily pulled apart.

Elasticity.—A property of matter which causes it to resume its original shape after some force has given it another shape. Rubber, steel, ivory, glass, etc., possess elasticity.

Hardness and Softness.—Properties of matter which are well known to us. The diamond is the hardest known substance.

Brittleness.—A property of matter which allows matter to be easily broken. Glass, china, etc., are good examples.

Solutions.—Place a crystal of potassium permanganate in a flask of water. The permanganate will slowly dissolve and color the liquid red. The dissolving of the permanganate illustrates the attraction of the molecules of water for the molecules of potassium permanganate. Sugar for sweetening coffee, and salt for seasoning food are other illustrations of this molecular attraction. Water dissolves many other substances, and in relation to such substances is called **a solvent.**

Different liquids have different solvent powers. Grease is not dissolved by water but by benzine, beeswax by turpentine, resin and shellac by alcohol.

1. What is the resulting mixture called?
2. What adjective describes a substance that may be dissolved by another.

Absorption of Gases.—The molecules of many substances attract the molecules of gases. Butter will have its flavor affected if any substance is placed near it which is emitting a gas or odor. Water absorbs air. The atmosphere holds water (moisture).

Substances which have gases dissolved in them may disclose the fact when, by heating, they are observed to give off the gases. Little bubbles of air may be seen collecting on the inside of a glass of cool water standing in a warm room.

Crystallization.—Any substances which have been dissolved in a liquid will return to a solid state if the liquid be evaporated. Evaporation of the liquid is an example of the molecules of a liquid escaping as a gas. An example of this may be seen in the liquid (sap) obtained from maple trees which when evaporated leaves behind maple sugar. If sea-water is heated until the water has evaporated, salt is left behind.

Dissolve about one ounce of alum in a cup of hot water. Hang two or three strings in the solution.

As the solution cools the molecules of alum as they collect on the strings arrange themselves in the form of beautiful crystals.

Osmosis.—Cut out the interior of a beet or carrot and fill the space with a thick

syrup or molasses. Close the top with a rubber stopper through which passes a long glass tube. Place the carrot in a bottle of water.

Water will pass through the walls of the carrot, mingling with the thick liquid. The water will pass into and through the carrot much faster than the syrup will pass out. This process of a liquid passing through thin membranes into a thicker liquid is called **osmosis.**

Plants get their food and water through the hair roots by this process. Oxygen gets from the lungs into the blood and fish absorb oxygen from the water by means of osmosis.

Inertia.—We have all experienced the tendency to forge forward if we have been standing in a moving vehicle which comes to a sudden stop. If we happen to be standing in a vehicle at rest and it suddenly starts, we have a tendency to remain in the same spot where we were standing, evidenced by our having to take a step backward quickly in order to keep our balance.

It is a property of all matter to persist in its state of rest, or in its state of uniform motion in a straight line, except as it is compelled by some external force to alter that state of rest, or of motion. That property of matter is called **inertia.**

Whenever an automobile or car stops, it must overcome the tendency to keep on going. Whenever an automobile or car starts, it must overcome the tendency to remain at rest. The "banking" of the outer rail higher than the inner rail on railway curves is to overcome the inertia which tends to make the moving cars resist the change of direction.

Gravity.—When one drops something from his hand he knows that the object will fall toward the earth. People who go up in aeroplanes know that a certain force is ever pulling them downward toward the earth. Those who jump from balloons know that parachutes are required to prevent the force from pulling them too quickly to the earth. This force which pulls things toward the earth also tends to keep them there. The waters of the sea, the rocks and soil, and all the objects, living and inanimate, are held on the surface of the earth by this force, called **gravity.**

When objects rise, as a balloon in the air or a cork in water, they rise because bulk for bulk they are lighter than the air, or the water. The heavier matter is drawn more strongly earthwards, and its heavier particles crowd beneath the lighter body, pushing it upwards.

Down.—Very few of us ever stop to think what "**down**" really means. Objects are said to fall down from any height. We seldom think that if two objects on opposite sides of the world should fall from the same height at the same time, those objects would move toward each other or, in other words, toward the center of the earth. *Down*, then, is the direction toward the center of the earth, and the *end* of "down" is at the center of the earth.

Up.—Up is away from the center of the earth, and the beginning of "up" is at that point, while the end of "up" is at a place indefinitely high above the earth. For example, if an object could move directly from the earth toward the moon it would be going up until it reached the place where the moon attracted it with greater force than the earth; and then it would be falling down toward the moon.

The Force of Gravity Varies with the Size of the Body.—The larger the body or planet the greater is the force of gravity of the body for objects on its surface. The moon is about $\frac{1}{50}$ as large as the earth. The pull of gravity on the moon is so much less than that of our earth that a body weighs only $\frac{1}{6}$ of what it would weigh on the surface of the earth, and a jumper who jumps 5 feet on the earth would be able, expending the same energy, to jump 30 feet on the moon.

Gravitation.—Gravitation differs from gravity. *Gravitation* means the force by which all the objects in space (the sun, the moon, the planets, the stars, the comets, etc.) are drawn toward each other. The "attraction of gravitation" is stronger in large bodies than in small. Large objects have a greater force of gravitation than small objects. The sun, the moon, the planets and stars are all held in their position by this great force of gravitation. *Gravity* means (as regards the earth) the pull toward the center of the earth exerted upon all objects in or on the earth, or within the range of the pull.

Spherical Forms.—**Experiment.**—Fill a small bottle about half full of water. Tip it gently. Fill the remaining part of the bottle with alcohol by allowing the alcohol to run slowly down the side of the bottle so that it will not mix with the water, but float on the surface. Drop a large drop of heavy oil into the bottle. Since the oil is heavier than the alcohol, it will sink until it comes in contact with the surface of the water. There sufficient alcohol and water have mixed so that the bubble of oil will rest in the mixture. The bubble of oil will assume a spherical shape. All material in a liquid form will assume a spherical shape if allowed to act freely.

Raindrops have a tendency to be spherical. Shot is manufactured by allowing streams of molten lead to run through fine holes from the top of a shot tower. These fine streams, before reaching the bottom of the tower, break up into little balls of molten lead which cool somewhat and

harden before striking water at the bottom of the tower. A splendid example of a liquid breaking up into spherical forms may be seen by turning the faucet until only a fine stream may be seen. Half way down the stream of water hundreds of little spheres of water are forming.

Questions

1. Why does one jumping from a height bend the knees on alighting?
2. In starting a load why does a horse have to give a harder tug than he does to keep it moving after it is started?
3. Why do we have great difficulty in stopping when running down hill, especially when carrying a heavy weight?
4. If the valve is suddenly closed after water has been running from the tap why will there be a noticeable thud?
5. Why do railway coaches "telescope" in a collision?
6. Why can an athlete make a longer running jump than a standing one?
7. Why will a train continue moving after the locomotive has been uncoupled and has "taken" a flying switch?
8. When a car moves swiftly around a curve, why are the standing passengers.impelled crosswise of the car toward the outside of the curve, although holding to the straps?
9. Why is snow "shed" from the shoes by kicking the feet against the doorstep?
10. When one shovels coal he swings the shovel full of coal forward, then suddenly stops the shovel; why does the coal continue forward?
11. When one jumps off a moving street car he is thrown violently to the ground. Why?
12. When a runner "stubs his toe" he falls forward. Why?
13. If one pulls a plate full of soup quickly toward him, the soup spills out on the opposite side. Why?
14. Why does snapping a cloth remove the water?
15. Why does the world keep turning?
16. Which way would an automobile tip over going around a curve; to the inside or outside of the curve?
17. Which way would you lean in riding around a curve in an automobile? Why?

18. Is the outside or inside rail banked on a curve of a railroad? Why?

19. Why does dodging help a hare to escape a hound?

20. If two cars met head on going at different rates of speed the occupants of which car would be likely to receive the greater injuries?

21. Why is it possible to pass over a piece of thin ice quickly, whereas stopping for a moment will cause the ice to break?

22. Why does the air remain on our earth?

23. If an apple falls from a tree does the earth move toward the apple?

24. Why will clothes-lines tighten up during a rainstorm?

25. Why is it possible to mark on the blackboard with chalk?

26. Why cannot one write as well on glass?

27. Why does a rough towel dry the body more quickly than a smooth one?

28. Why is it possible to make a mark on paper with a lead pencil?

29. Why is it not possible to write on paper with a slate pencil?

30. Why does salt become damp?

31. Why must pails and tubs made from wood be kept damp?

32. Why do some people place flour on a fresh ink stain on the tablecloth?

33. Why is it almost impossible to remove kerosene or ink stains from marble?

34. Why does oil float on water and alcohol mix with water, both liquids being lighter than water?

35. Why does molasses stick to things?

36. Why does glue make things stick together?

LOCATION

Direction: The Cardinal Points.—*East*, speaking loosely, is the general direction of the sunrise; *west*, of sunset. More accurately, east is the point on the horizon at which the sun rises on March 21 and on September 22; west, the point on the opposite horizon at which the sun sets on those dates, which are called the equinoxes.

Standing with the extended right arm pointing due east, and the left arm pointing due west, one faces in the direction called *north*. The direction exactly opposite to north is called *south*

At night, one can determine direction by locating the star called Polaris, called also the pole star, and the north star. Anyone may easily learn to locate readily the north star. Its direction from any observer is virtually north. Based on the direction of the north star, tell how to determine the direction of: 1. The east. 2. The west. 3. The south.

The common method of determining direction when accuracy is important is with the *compass,* an instrument which employs a bar of magnetized steel, or a dial card with needles, so suspended that the bar on the card will swing freely in a horizontal plane. The bowl of the compass is constructed of copper or brass, and the dial is fitted with an agate cup in the center, placed upon a sharp point to allow the needle or dial to swing freely.

For use on ships compasses are so constructed that the dial floats in alcohol to keep the card level as the ship rolls and pitches. The compass does not point to the north pole of the earth but to a north magnetic pole on Boothia Island in Northern Canada. *Find the island on the map.*

The amount of variation between the north pole and the north magnetic pole is called the **magnetic declination,** and navigating officers must allow for this in working out the true north when sailing. They are provided with government charts which show the exact amount of declination.

Find in the unabridged dictionary the picture of a compass. Notice that there are 32 prominent divisions, or points, marked on it. These 32 points are called *points of the compass.* The four principal points, east, south, west, north, are called the *cardinal points.* When a compass is properly set, the cardinal points of the compass will point to the corresponding directions, namely, east, south, west, north; and the name cardinal points is also given to these directions.

Longitude.—The longitude of any place on the earth is measured east and west of a prime meridian according to the difference between Greenwich and the place.

The units of measure are degrees, minutes, and seconds. The distance around the earth is divided into 360°.

The Greenwich Royal Observatory is located in the eastern part of London on the Thames River. From the meridian on which this observatory is located *longitude* is usually reckoned. For example, if it is 6 o'clock in the morning at a certain point on the earth when it is 12

o'clock at Greenwich there is a difference of 6 hours in time. One hour corresponds to a difference of 15°. If a place has a difference in time of 6 hours from Greenwich, then there will be a difference of 90° in longitude.

Every ship carries a kind of clock called a **chronometer** which is set to tell Greenwich time. By observing the sun through an instrument called a **sextant,** one is able to determine the exact time of the day at the place of observation. By computing the difference between this time and the Greenwich time (chronometer time), one can determine the longitude of the place.

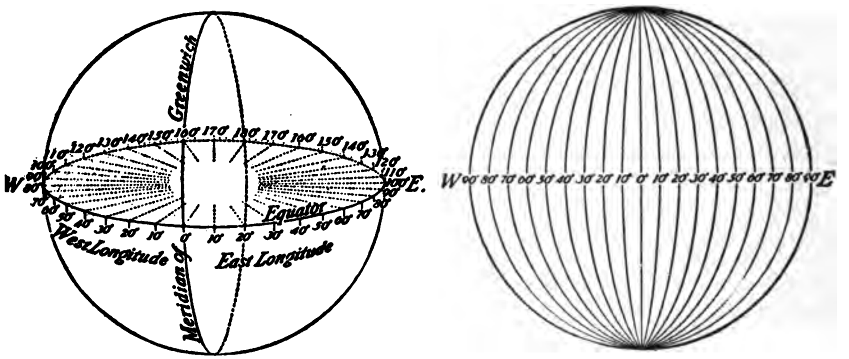


FIG. 203.

When the time by the sun is *later* than the time by the chronometer, the observer must be east from Greenwich, and his longitude is called *east* longitude. For example, if the chronometer shows that it is 10 o'clock A. M. at Greenwich but the sextant indicates 11 o'clock A. M. at the spot where the ship is, the ship is 15° *east* longitude. If a ship records 9 o'clock A. M., when the Greenwich time is 10 A. M. the ship is 15° *west* longitude, since the time is earlier than Greenwich time.

A Table of Longitude and Time:

360° of longitude corresponds to 24 hours of time.
15° of longitude corresponds to 1 hour of time.
1° of longitude corresponds to $\frac{1}{15}$ hour or 4 minutes of time.
15′ of longitude corresponds to 1 minute of time.
1′ of longitude corresponds to $\frac{1}{15}$ minute of time.
15″ of longitude corresponds to 1 second of time.
1″ of longitude corresponds to $\frac{1}{15}$ second of time.

International Date Line.—If you should start to travel west from Greenwich to go around the world, you would need to set your watch back one hour for every 15° of longitude passed over. By the time you had traveled around the world you would have set your watch back 24 times, or 24 hours. You would thus have lost a whole day. If you started eastward from Greenwich you would set your watch ahead 24 times, thus gaining a day in traveling around the world.

To overcome the difference of the extra day, all nations, in 1884, agreed upon a place where the day should begin and end; or, in other

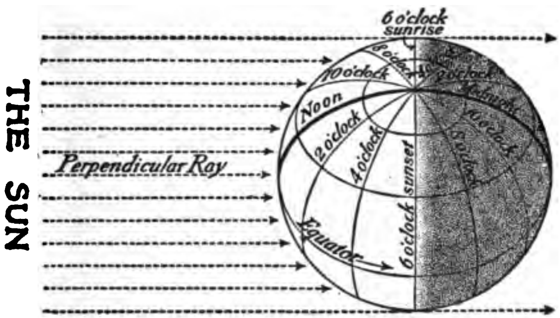


FIG. 204*a*.—The time on different meridians when it is noon on the prime meridian.

FIG. 204*b*.—International date line.

words, where time should be read. This place is the 180th meridian east and west of Greenwich, and is called the **International Date Line.** This line does not follow the 180th meridian exactly, but is somewhat zigzagged, so as not to cut some of the islands in the Pacific Ocean into two parts, with the result that if it were Monday, say, in one part, it would be Sunday, or Tuesday in the other. On a ship crossing the International Date Line on a Monday, traveling westward, the day would forthwith be called Tuesday; traveling eastward, Sunday.

Standard Time.—If you were riding in a train from New York to Buffalo and the West, the train, arriving at Buffalo at 1 o'clock by your watch, set at New York time, might leave Buffalo at 12.10 by the clocks of Buffalo; in other words, the time west of Buffalo is 1 hour behind

the time at New York, and you would make it convenient to set your watch accordingly. If you were to travel across the country until you reached North Platte, Nebraska, again the local clocks would be one hour behind your watch which again would need to be set back. Likewise on arriving at Sparks, Nevada. From the time you left New York to your arrival in San Francisco, California, it would have been necessary to set your watch back a total of three hours, for it to agree with the clocks there.

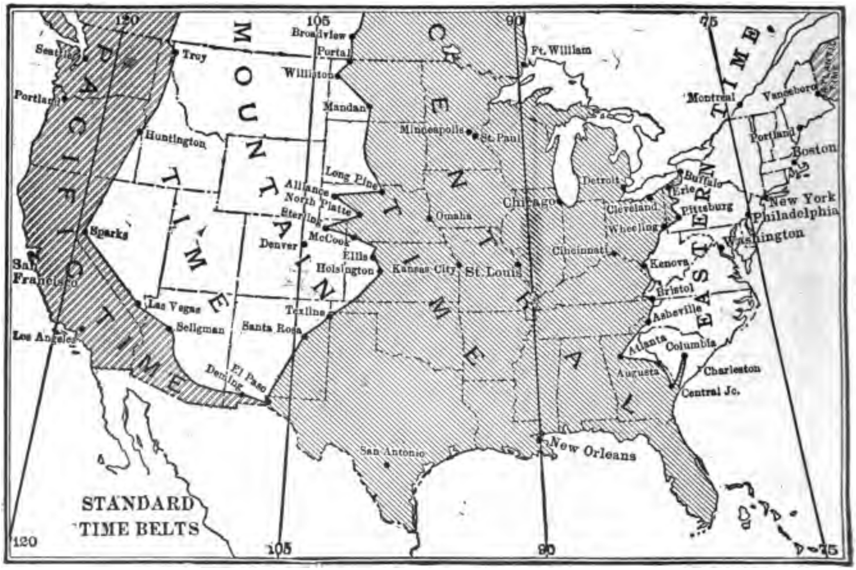


Fig. 205.

This arrangement of time for our country by zones from east to west (or west to east) is for convenience, and was adopted by common consent, and called **standard time.**

When the sun is on the meridian of any town it is really 12 o'clock noon, and the time of all places east or west at that moment is earlier or later than noon. But the same is true of every other place at meridian noon. To run railroads by timetables, printed to fit each town's local meridian noon, would be impossible. In some places this time according to the sun is still used, and is called **sun time,** and the time by which the trains run is called **train time.**

Latitude.—Not only is it necessary for ships and people to know their distance east or west of the prime meridian, but also to know their distance north or south from the equator. To aid in determining distances north and south from the equator the earth has been divided into imaginary circles running around *the earth* parallel to the equator.

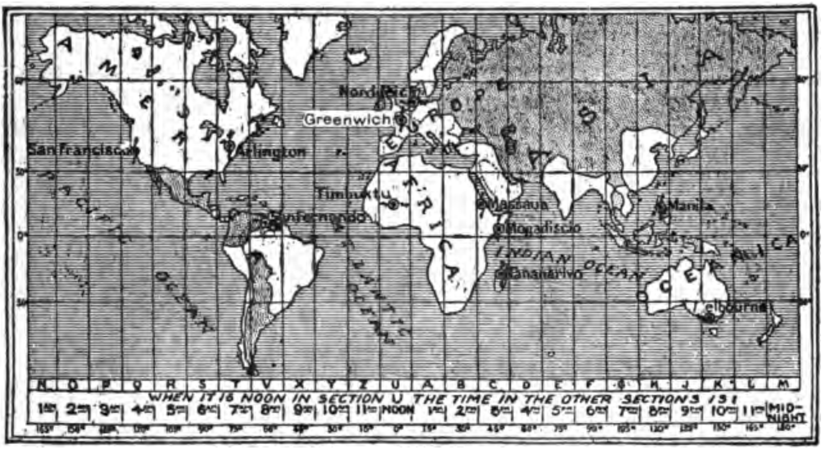


FIG. 206.—A map showing the proposed standard time belts of the world. We have seen how the distance traveled by a ship each day is found by comparing the local or ship's time with Greenwich time, the ship's time being determined by the position of the sun or stars, the Greenwich time by the vessel's chronometer. From this it will be noted that the difference east or west between any two places is merely the difference between the two local times expressed in degrees. No way has ever been found, however, for making a ship's chronometer keep exactly correct time. At times the clock's error is such as to render the accurate finding of the ship's position impossible; and in such cases, when the vessel is near land, disastrous results may follow. With the scheme of the International Conference the wireless signals will act as a check on the chronometers. The great importance of this may be realized when it is remembered that an error of one second in calculating the time at sea means an error, in determining the ship's position, of something like 1000 feet.

The equator is an imaginary circle midway between the poles and is marked 0 (zero) **latitude.** The distance from the equator to the north pole is divided into 90°; likewise the distance from the equator to the south pole.

A person in Maine, Ottawa, Canada, Michigan, Oregon, etc., is in 45° north latitude or one-half way to the north pole from the equator. A man in Central Illinois, near Springfield, is in 40° north latitude and 90° west longitude. At 9 o'clock in the morning in this place, it is 3 o'clock in the afternoon at Greenwich.

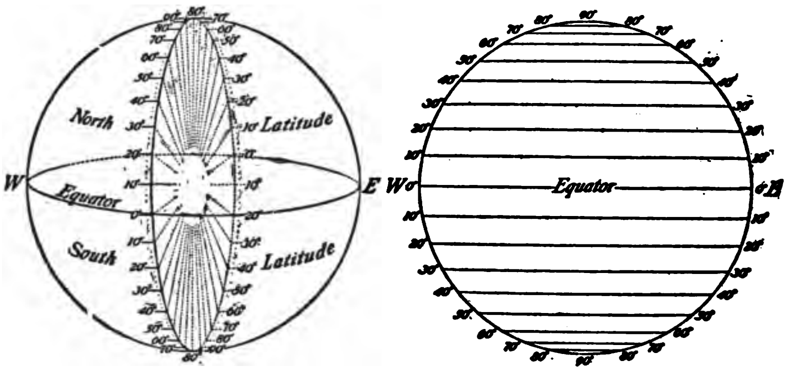


FIG. 207.—Degrees of latitude and parallels by means of which points are located on the earth as north or south of the equator.

QUESTIONS

1. How can all places on the earth be located, east and west?
2. If a vessel is at 13° North latitude, 80° East longitude, and the sun time is 5 P. M., what time is it at Greenwich?
3. What causes the sun to seem to rise?
4. How would you determine the direction north if you were without a compass and the sun were not shining?
5. Why is the north star a better means than the compass for obtaining direction?
6. O what use would the compass be to one seeking the North Pole?
7. What time is it at Greenwich now?
8. What day is it at Greenwich now?
9. What time is it in China?
10. What day is it in China?
11. If you should travel from New York through San Francisco to Peking, China, how many times would you change your watch? Would you lose or gain time? How much?

12. Are there any places on that journey where you would change time from one day to another? Why?

13. Why was it necessary to have a place from which to reckon time?

14. Find two places less than 100 miles apart where the people in one place called the day Thursday and the people of the other place Wednesday?

HEAVENLY BODIES

Ancient Knowledge.—From time immemorial man has studied the universe. He has been interested in our own moon, the sun and our fellow planets of the solar system, the stars and other heavenly bodies and phenomena. They have a certain element of mystery. The Chinese claim to have made many discoveries several thousand years B. C. Shepherds of olden times without other instruments than their own eyes watched, studied and made records of things they saw in the heavens. The Greeks did much to classify knowledge which had been gained regarding the universe.

The Sun.—The heavenly body which perhaps is the most familiar to us is the sun? It is about 93 millions of miles from the earth.

Light of the Sun.—The light from the sun is equal to that which would come from 6000 wax candles alight at a distance 1 foot from the eye. It would require 600,000 full moons to produce a day as brilliant as a sunlit clear day.

The sun is presumably blue, but has a tendency to appear red, probably because red rays pass more readily through our atmosphere, the blue rays being refracted.

Heat of the Sun.—It has been estimated that if the heat of the sun were produced through the burning of coal, about 8 trillion tons per second would be required—enough coal to supply the entire world for many years.

Read again that part of Chapter VI treating of *the production of light and heat;* and also the first two paragraphs of Chapter IV.

Size of the Sun.—The volume of the sun is one million three hundred thousand times that of the earth and its weight about 198,000,000,000,000,000,000,000,000,000 pounds. So strong is gravity's pull there,

because of this enormous weight that a man weighing 150 pounds on earth would weigh about 2 tons on the sun. Even his feet would weigh several hundred pounds.

Sun-Spots.—Frequently, on the surface of the sun, dark spots appear on one side, move across its face and disappear on the other side. This movement takes place because the sun also rotates on its axis.

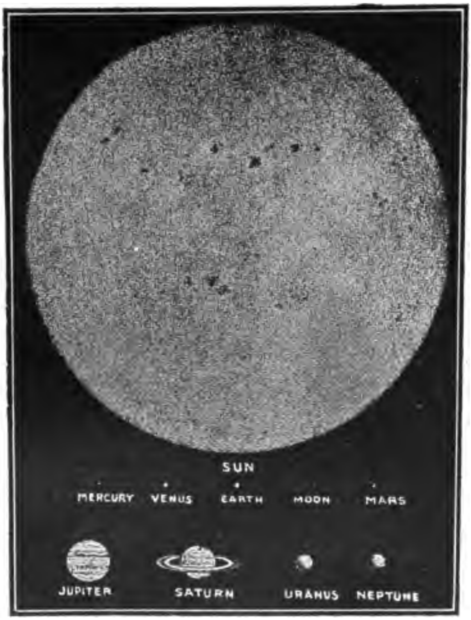


Fig. 208.—Relative sizes of the planets and the sun.

Sun-spots look dark, but merely by contrast, for in reality they are intensely bright—far brighter than any terrestrial source of light. They are uprushes of vapors in which the vanadium and titanium are distinguishable, together with iron and many of the other common metals. The sun-spots are immense vortices, like the water-spouts seen at sea, with the trumpet-shaped part at the top. As these immense vortices whirl, the vapors of the heavier metals are carried from within outwards, and are cooled sufficiently to produce oxides which fall back again into the sun's fiery mass. Possibly it is because of the relative coolness of these oxides that the sun-spots look dark.

The Moon.—Next of interest to us in the sky is the moon. The moon is about 239,000 miles from the earth.

An aeroplane traveling continuously at a mile a minute in a bee line from earth to moon would be 23 weeks and 6 days making the "new record."

The moon, turns on its axis once in 27½ days, which means that daytime on the moon is as long as 14 of our days, and that a night there is of equal duration.

When the moon rises or sets it appears to be considerably larger at

and near the horizon than in the open sky. There are two reasons for this:

1. We are looking through a longer reach of atmosphere, the effect being to magnify the apparent size of the moon.

2. We are comparing the size of the moon with other objects in line with the horizon.

FIG. 209.—Mountainous surface of the moon.

No one has ever seen the other side of the moon because, although it does revolve about the earth, the same side is always toward us. The ancients early noticed that the moon rises nearly an hour later (53 mintues) each night, and at certain times each month does not appear during the night at all.

The light of the full moon is only about $\frac{1}{600000}$ that of the sun. During the moon's long daytime the temperature must rise to a tremendous height, and during the long nighttime drop far below zero.

Dry and Wet Moon.—When a line joining the points or horns (cusps) of the crescent moon lies nearly parallel to the horizon the moon is called the "dry" moon, because in that position, according to the fancy, it would not spill water (onto the earth). When that line is perpendicular to the horizon, the crescent then being "tipped over," the moon is called a "wet" moon, because then in the position to spill water.

There have been many superstitions regarding the moon and its influence. One of these, still quite popular, is that the moon controls our *weather;* that, of course, is not so. The direction that the crescent faces has nothing to do with the weather. The crescent form of the new moon is a mere matter of the relation of the shadow to the illuminated surface of a spherical body lit from one side only, and viewed by the observer from certain angles. There being no air on the moon, it has no twilight

the sky is black and dotted with stars, even at midday. There are no gorgeous dawns or sunsets, for the day breaks and the night falls instantly.

The Man in the Moon.—The moon appears to be dotted here and there with mountains and volcanic craters. When the sun strikes

FIG. 210.—Different phases of the moon.

these elevations obliquely the shadows are distinctly seen, causing the appearance of the "Man in the Moon," or the "Lady in the Moon."

All these mountains and craters have been named, mostly after men distinguished in science. Copernicus is the largest volcanic crater. It is situated on the top of the nose of the man in the moon. Its diameter is 46 miles.

Tides on the Earth.—Twice a day, about 12 hours and 25 minutes apart, the water of the ocean begins to move toward the shore. This motion continues for about 6 hours, and is called **flood tide.** For the next 6 hours the water trends back in the motion known as **ebb tide.** The tides are caused principally by the moon pulling the water of the oceans. Since the water is free to move, it trends toward the sun and the moon as their relative direction from the oceans changes because of the earth's rotation on its axis.

Fig. 211.—Eclipse of the moon.

If the sun and the moon are on the same side of the earth, we have very high tides on the side of the earth toward the sun and the moon and on the side of the earth directly opposite. Likewise if the sun and moon are on opposite sides of the earth the tides are high. When the sun and moon are on the same side, it is said that they are **in conjunction;** on opposite sides, in **opposition.** When the sun and moon are in conjunction or when in opposition, the high tides are called **spring tides,** but when the sun and moon are pulling at right angles, the tides are called **neap** tides. The moon pulls the water with greater force than the sun because the moon, though so much smaller, is enough nearer the earth to more than offset the greater but more distant sun's pull.

The Earth.—The earth is one of the small planets. Because of its rapid motion it became flattened at the north and south poles, when it was in a molten mass. A sphere which, like the earth, is more or less flattened at the poles, is called an **oblate spheroid.**

The diameter of the earth from pole to pole is 26 miles shorter than through the earth at the equator. The earth's average diameter is about 8000 miles and its circumference about 25,000 miles. The curvature of the earth averages about 8 inches per mile.

The earth turns on its axis once in 24 hours; however, we all know that day and night are not of the same length at all times of the year. The difference is caused by the inclination of the axis of the earth.

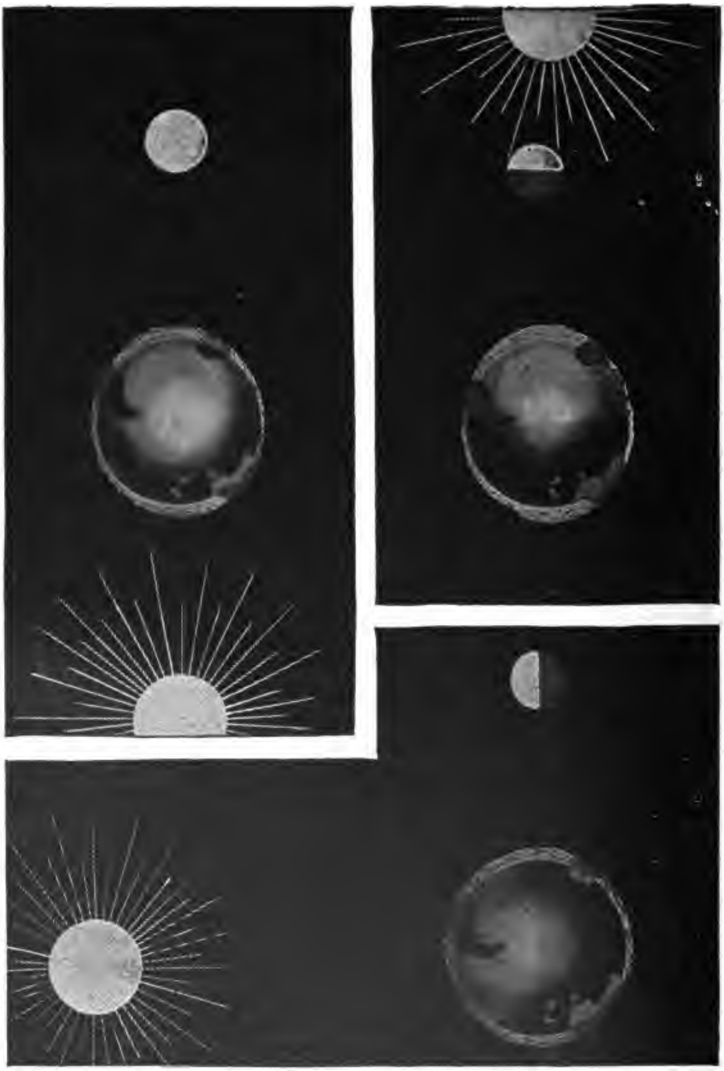


FIG. 212.

Top left—sun and moon in opposition, occasion of spring tides.
Top right—sun and moon in conjunction, occasion of spring tides.
Bottom—Sun and moon, occasion of neap tides.

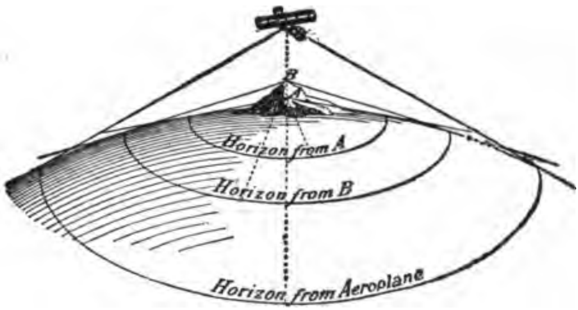


FIG. 213.—The broadening horizon seen from different elevations.

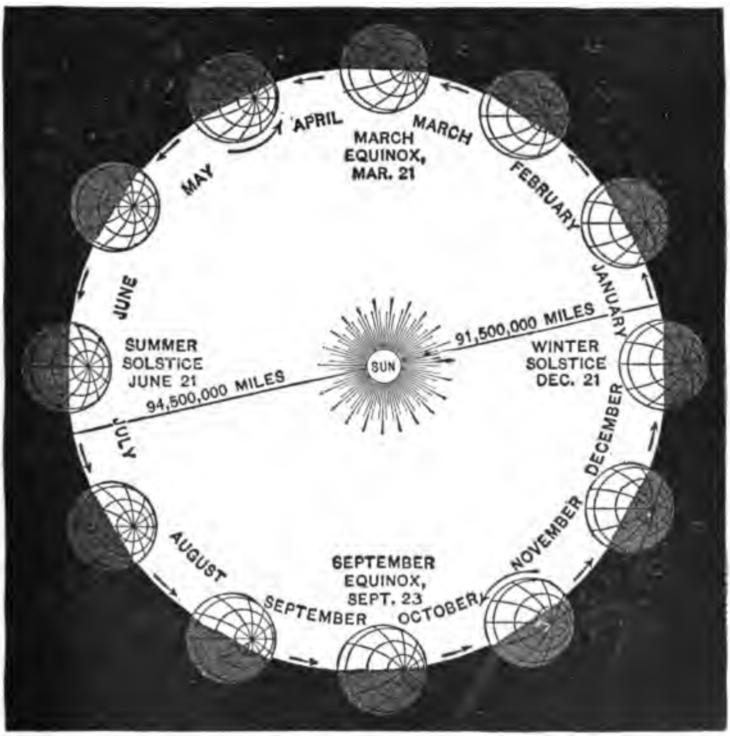


FIG. 214.—Position of the earth in its orbit each month. What does *solstice* mean? *Equinox?* Why is December 21st called the *winter solstice?* June 21st the *summer solstice?* March 21st and September 22d the equinoxes?

The north polar regions have a night lasting about six months, and a day equally long (as will be seen by one of the diagrams). Likewise the south polar regions, but the opposite as to the day and night periods.

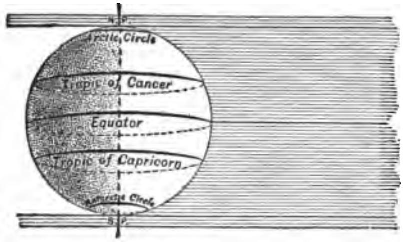


FIG. 215.—The position of the earth at the equinox.

The earth travels around the sun in an orbit once every year of 365¼ days. Because of this extra fourth of a day it is necessary to add one day to every fourth year. We call this year a leap year. The true length of the year is 365 days, 5 hours, 48 minutes and 46 seconds. Adding the one day to every four years makes the average length of a year 365 days and 6 hours. This makes the year 11 minutes and 14 seconds too long, which amounts to over 3 days in 400 years. The year at the beginning of every century is not a leap year unless it is divisible by 400—an arrangement which corrects the discrepancy.

Meteors.—On some starry night you may have seen a **meteor** dart across the sky. A familiar name for these is *falling stars* or *shooting stars*. They are small solid bodies, sometimes so small as to weigh only a fraction of an ounce. Meteors are apparently errant bodies traveling through space, those which visit us being drawn towards us by the earth's attraction or pull. They have a tremendous speed, which causes friction so great when they come within the atmosphere of the earth that they become white hot, and usually burn up. Sometimes meteors, weighing a number of tons, instead of burning up, fall to the earth.

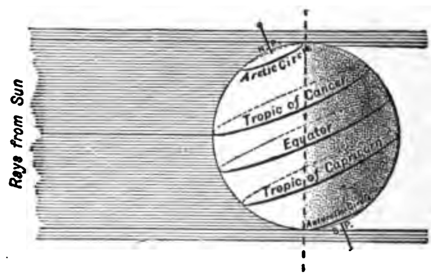


FIG. 216.—Position of earth at summer solstice.

Origin of the Solar System.—It is believed that millions of years ago all the bodies we know about in the solar system existed as a mere cloud

called a **nebula**—a cloud of heated vapor and particles of matter, the whole moving through space, but also having a "whirl motion" of its own. The central part, according to the theory, gradually formed itself into the sun; and, farther out in the whirl, the planets one after another, and their moons, took form. Possibly, other bodies are even now in process of forming. Possibly, the distant stars are centers of similar systems similarly formed through countless eons of time?

All the heavenly bodies are believed either to be or to have been:—intensely hot, like our sun; or completely cooled off, like our moon; or else of some temperature

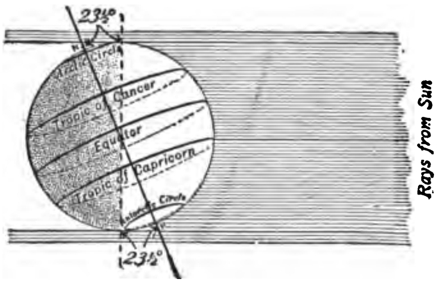


FIG. 217.—The earth at the winter solstice. What part now has continuous day? Night? Where would the nights be shorter than the days? Why? Where would the sun just "set" and begin rising again?

between the two. All are believed to be, or to have been, growing smaller—contracting—and to have grown hotter and hotter in the process because of the resulting compression. Yet some, like our moon, the contraction completed, have grown cold.

OTHER PLANETS

Mercury.—Mercury is so near the sun as to be observed only with the greatest difficulty. One side of the planet has perpetual day and the other perpetual night, which means that one side must be intensely hot while the other side is cold.

Venus.—On the sun side the dry atmosphere is filled with dust which the sun's light so illumines as to give Venus a very beautiful appearance.* Venus is the brightest of the planets because the reflecting power of the surface is so great. When seen nearing the horizon at sunset it is called

* Originally thought to be due to the sun shining on clouds.

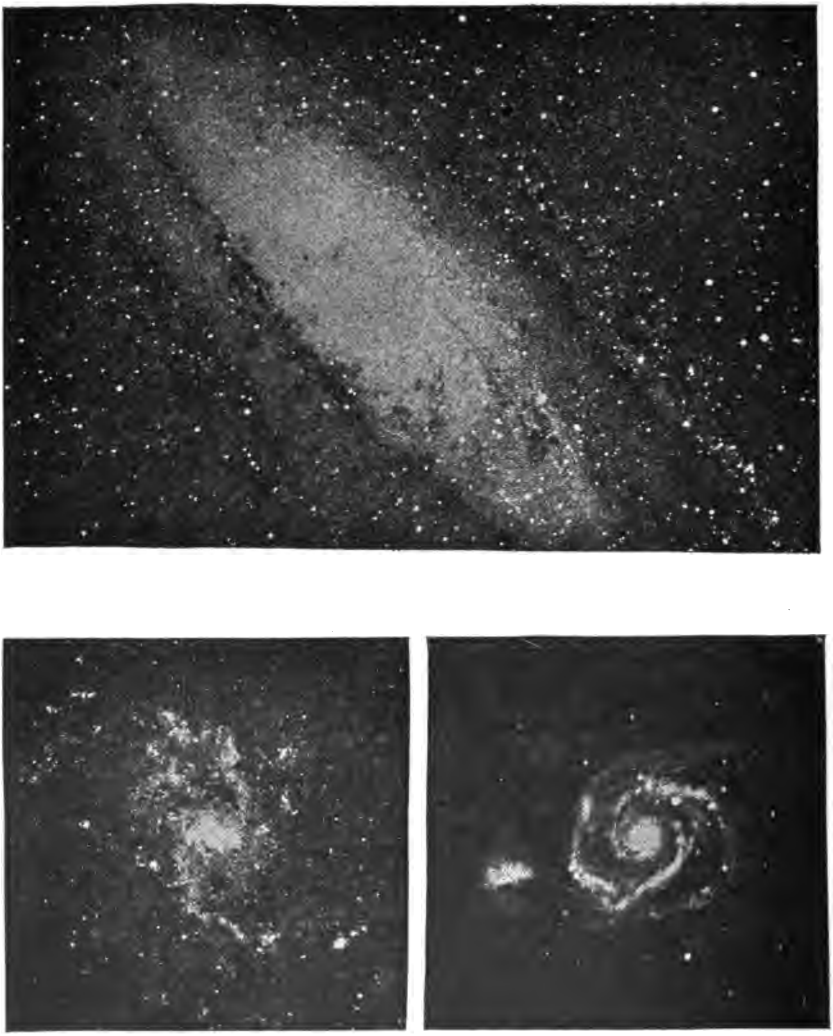


FIG. 218a, b, c,—According to one theory the nebulæ illustrated in the above photographs represent systems in formation. According to this theory our own solar system originated from a nebula similar to these.

the "Evening Star," and when seen in the east at the approach of dawn, it is called the "Morning Star." That side of Venus facing away from the sun is probably covered with ice.

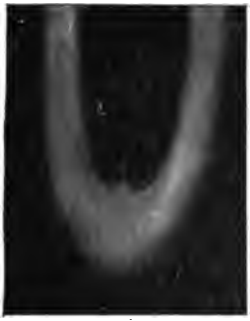


FIG. 219.—The head of a comet.

FIG. 220.—The comet of 1918.

FIG. 221.—The effects of cooling a warmed apple.

Am. Mus. Nat. Art.

FIG. 222.—The Cape York meteorite which weighs 36.5 tons.

Mars.—Mars sometimes appears in the sky reddish in color. Probably because of this, the planet received the name of the Roman war god, Mars. Mars is especially interesting to us because the planet is much like our own. Indeed, there are astronomers who insist that Mars is inhabited, perhaps by people more or less like the human race. This belief has not been confirmed.

The Martian day is about the length of ours. There is a north pole and a south pole the changes in whose appearance at different seasons are as if snow comes and goes. There are two moons, probably not over 10 miles in diameter, one of which travels so fast that it goes around Mars three times a day.

The planet is surrounded with an atmosphere believed to be much rarer than our own. Five quite straight lines, of unchanging position, which cross its face in several directions, so resemble *canals* that some astronomers maintain that they are artificial, that the color of their borders is due to vegetation, and that the prevailing red tone evidences great stretches of desert land; others confidently oppose the belief that there is life on this planet, either vegetable or animal, and that the so-called canals are artificial.

Jupiter.—Jupiter is the largest of all the planets. Its volume is more than 1300 times larger than the earth's, but its weight only 316 times greater. Jupiter has eight moons, four small ones and four large ones; the four large ones may be seen with even a small telescope. Next to Venus it is the brightest of the planets. Its day is less than one-half our day—9 hours as against 24 hours—but its year is nearly twelve of our years.

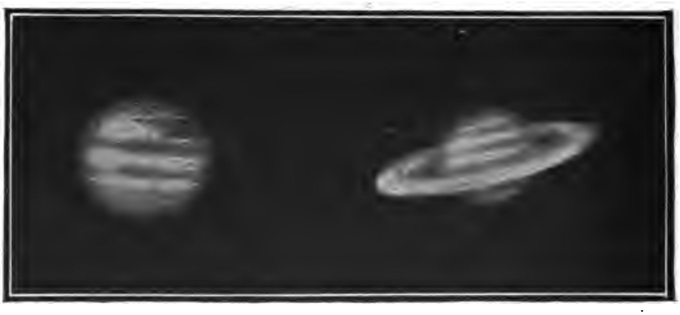


FIG. 223.—The planet Jupiter. The ringed planet Saturn.

Saturn.—Saturn is one of the most beautiful planets in the heavens. It is surrounded by three rings of gaseous vapor of which the middle and broadest one is probably about 10,000 miles wide. The planet changes position so that the rings may be seen more easily at certain times.

Uranus and Neptune.—Further out in space is the planet Uranus, which has four moons, all peculiar in that they move backwards in

their orbits. Its mass is about 14½ times that of the earth, so that gravity on the surface of Uranus is so much greater than gravity on the earth that if a man could be on Uranus his feet and hands would be so heavy he could not lift them; indeed, his own weight would crush him to death.

Beyond Uranus and not visible to the naked eye, lies the planet Neptune with only one moon. Its journey around the sun takes 164 of our years. Its discovery (in 1846) was a feather in the cap of mathematical astronomy, the position where it ought to be found, and the exact time when to look for it there, having been correctly determined by mathematics. Neptune is farther from the sun than any other planet now actually known.

An Undiscovered Planet.—By mathematics is predicted the discovery soon of still another planet, even farther away than Neptune. According to the calculations it should be larger than the earth, how much larger has not been determined.

The Small Planets (Asteroids).—Beyond Mars there are a number of tiny planets, so small that the diameter of the largest is only about 500 miles, and some of them so small that a person would be able to ride around one in a few minutes in an automobile. A farmer would need the entire planet for his garden. The pull of gravity on some of these is so slight that a man could leap 60 feet and descend with as little jar as the athletes shown in the slowed-up moving pictures. These planets collectively are called **asteroids.**

Stars.—The stars, like our sun, which is itself a star, are incandescent, and each shines with its own light. Each twinkling star may have a system of worlds or planets traveling around it. If some of the worlds are inhabited, our sun may be visible from them shining only as a small star in their far distant unknown.

The stars seem to be too numerous to count, but in reality only about 6500 stars are visible to the naked eye, and of these only about 2000 are visible at one time. About 100,000 are made visible by a good opera-glass. With the aid of a powerful telescope the number of stars seen increases to many millions.

How the Distance to the Stars is Measured.—The distance to the stars is measured in a very interesting way: Let us look at some object a short distance from the spot we happen to be on, and then step in a straight line to some other spot and look at the same object again.

INFORMATION ABOUT

Planet: In Order According to Distance from Sun.	Distance from Sun, Miles. Average.	Distance from Earth, Miles.	Time Required to Reach it Traveling on Express Train 1 Mile per minute Years.	Size Compared with Earth.	Surface Compared with Earth.	Density.
Mercury...	36,000,000	48,500,000 to 137,500,000	110	$\frac{1}{20}$	$\frac{14}{100}$	3.70
Venus......	62,200,000	25,000,000 nearest distance	50	$\frac{9}{10}$	$\frac{93}{100}$	4.89
Earth......	92,900,000	0		1	1	5.53
Mars......	141,500,000	34,000,000 nearest distance	76	$\frac{1}{7}$	$\frac{28}{100}$	3.95
Jupiter.....	483,300,000	390,000,000 averagé	740	1264	116.9	1.33
Saturn.....	886,000,000	793,000,000 nearest distance	1470	759	83.3	0.72
Uranus.....	1,781,900,000	1,688,900,000	3160	63	15.9	1.22
Neptune...	2,791,600,000	2,700,000,000	5055	82	18.9	1.11

OUR PLANETS

Light and Heat Compared with Amount Reaching Earth.	Year, Length.	Day, Length.	Rotation On Axis.	Speed In Space.	Moons, Number.	Weight of One Pound.	Atmosphere.
6.8	88 days or $\frac{24}{100}$ year	Perpetual day and night	Once during journey about sun	1773 miles per minute		$5\frac{1}{2}$ oz.	No.
1.9	$7\frac{1}{2}$ mo. or $\frac{62}{100}$ year	Ditto	Ditto	1296 miles per min.	None	13 oz.	Dense & cloud-less
1	12 mos.	24 hrs.	17 miles per min.	1102.8 miles per min.	One	16 oz.	Yes
$\frac{1}{2}$	1.88 year	24 hrs. 37 min. 22.7 sec.	9 miles per min.	900 miles per min.	Two	6 oz.	Yes
$\frac{1}{27}$	11.86 years	9 hours 55 min.	473 miles per min.	483.6 miles per min.	Eight	42 oz.	Very dense
$\frac{1}{100}$	29.46 years	$10\frac{1}{4}$ hours		366 miles per min.	Ten	$18\frac{1}{2}$ oz.	Very dense
$\frac{1}{368}$	84.02 years	about 10 or 12 hrs.		252 miles per min.	Four	$10\frac{1}{2}$ oz.	Very dense
$\frac{1}{900}$	164.78 years	19 hours		$201\frac{3}{5}$ miles per min.	One	$14\frac{2}{5}$ oz.	Very dense

Draw a line as if from the first position to the object and another one as if from the second position to the object, forming an angle. Step back to the first position and look at some object farther away than the first one. Move again to the second position and view the same object. We find the new angle formed to be much smaller than the first angle. We learn that the farther the object is from us the smaller the angle becomes, although the base line from one spot to the other spot is the same.

The basis for the calculation of the distance of stars is measured much in the same way except that instead of two spots on the earth two positions of the earth in its orbit are chosen as a base line from which to observe a star. This base line is the mean radius of the earth's orbit (the earth's distance from the sun), and can be used to view the angular displacement of stars viewed, just as a surveyor may use a base line to measure the angle displacement of objects on the earth, or as we paced and used our base line as explained above. In the case of the stars this displacement is called the **parallax.** Alpha Centauri, probably the nearest star except our sun, judged by the angle of parallax, is about 25,000,000,000,000 miles distant.

To find the distance of any star from the earth we divide 19,000,000,000,000, the mile value of one second,* by a fraction representing the actual parallax. For example, the North Star has a parallax of 0″.06. Dividing 19,000,000,000,000 by 0″.06 we get about 316,666,666,000,000 miles.

Computing parallax is an extremely difficult process, to be done successfully only with instruments of the utmost delicacy and accuracy. Below is a list of parallaxes of the most important stars. Work some of them out and determine their distance from us. Those which have all zeros signify that the distance is so great that no angle can be obtained.

Polaris (the North Star), 0″.06; Aldebaran, 0″.11; Capella, 0″.09; Rigel, 0″.00; Betelgeuse, 0″.02; Canopus, 0″.00; Sirius, 0″.37; Castor, 0″.20; Pollux, 0″.06; Procyon, 0″.30; Regulus, 0″.02; Arcturus, 0″.03; Alpha Centauri, 0″.75; Antares, 0″.02; Vega, 0″.11; Altair, 0″.23; Deneb, 0″.00; Fomalhaut, 0″.13.

The figure 19,000,000,000,000 is obtained by multiplying 93,000,000. the radius of the earth's orbit, by 206,265, the distance from us of an object having one second of arc as its parallax. The number equals 19,172,645,000,000, but for convenience just 19,000,000,000,000 is chosen as an adopted standard of measurement for the distance of stars. The name applied to this number is the *parsec.*

Comets.—Comets occasionally visit the solar system. The comet usually has a long tail millions of miles in length. The comet and tail (see Figs. 219, 220) are supposed to be composed of particles of carbon, sodium, iron and magnesium enveloped in a luminous gas. Occasionally

* Second of arc, not second of time.

the comet breaks up and the fragments continue on their way as meteors. Sometimes the earth passes through a swarm of meteors. At such a time the sky seems to be full of shooting stars, so called.

Comets pass into space and sometimes return a great many years afterwards. Others go near the sun and after passing very close to it rush off into space probably never to return. These strangers of space are very interesting. In olden times people thought that they foretold war, famine and many other sufferings.

Constellations.—To view the heavens on a clear and moonless night is to be sobered if not indeed overwhelmed by the almost endless vista of suns beyond suns and systems upon systems. The mind of the ancients could not grasp the vastness of the universe. In a childlike way they traced the outlines of men and beasts based on groups of the stars, and invented a pleasing story about each. The groups of stars in these imaginary pictures are called *constellations.*

Movement of Stars.—The stars seem always to be in the same place, but in reality they are moving through space. Some of the stars are traveling at enormous rates of speed, but they are so far away that it would require years to detect any movement even if any star should move one million miles per day. Our own star, the sun, is moving at the rate of about 800 miles per minute. Scientists believe that stars are all moving around some great center or centers.

Nebulæ.—It is believed that not only our solar system but all the stars and their systems originated in vast gaseous whirls called nebulæ (meaning clouds). Nebulæ are even now scattered throughout space as masses of misty light moving through space like stars. Read again the topic "Origin of the Solar System" (above).

Only two or three of the nebulæ can be discerned without a telescope. A blur of light surrounding the third star of Orion's sword is one of the nebulæ which may be observed with the naked eye. It is estimated that some of the nebulæ are so far away as to require 8,000,000 years for their light to reach us.

Age of the Stars.—The color of the star tells us something as to the age of a star. When they are young, stars are composed of thin gas and shine with a blue or white light. The star Rigel (re-gel), below the belt of Orion, is a white star.

The older the stars grow, the more condensed they become, and the more their light resembles that of the sun. As they grow older, they

also become red. Betelgeuse in the constellation of Orion is an example of a red sun. Brilliant white, violet, blue, green, yellow, orange, red and fiery red are all familiar colors, each star having its own hue.

When the stars become very old they lose all color and heat. There are many such stars, each representing a sun which has become cold and desolate.

FIG. 224.—Position of the Big Dipper at a given hour at different times of the year. The position changes throughout the 24 hours.

Size of Stars.—The stars vary in size. It is possible we do not see the largest suns in the universe. **Canopus** (ca-no′-pŭs) is believed to be larger and greater than Sirius (sĭr′-ĭ-ŭs). This star is visible in the southern hemisphere, and looks only about half as bright as Sirius. Canopus'

distance from us is so unthinkably immense, and its size so far beyond our ability to estimate, we cannot begin to realize the wonder of this huge sun.

Constellations and Important Stars.—Ursa (ûr′-sȧ) **Major and Ursa Minor,** the Big Bear and Little Bear (Big Dipper and Little Dipper), get their names from an ancient story of a beautiful mother called Callisto (kă-lĭs′-tō), Juno's maid, who had a little son named Arcus (är′-kŭs).

Juno was piqued by Callisto's beauty, and so she changed her into a bear. When Arcus grew up he became a hunter and was about to kill his mother when Juno, realizing the danger, put them both in the heavens as stars and caused them to keep moving around and around Polaris, instead of rising and setting like other stars.

Polaris (pō-lā′-rĭs), the **North Star,** is the most important star in the constellation of Ursa Minor. It is the last star in the handle of the Little Dipper (Fig. 227). A line drawn through the last two stars in the end of the Big Dipper, from the bottom to the top, and extended will pass through Polaris. The star receives its name from the fact that the earth's orbit points at it. The distance to the Pole Star is so great that it requires about forty-six years for the light to come to us.

Draco is represented by a figure of a long serpent stretching between Ursa Major and Ursa Minor.

Cassiopeia (kăs′ĭ-ō-pē′ya) is represented as a queen seated on her throne. On her right is her husband, King Cepheus (sē′fūs).

Juno and Jupiter became angry at Cassiopeia because of her boast that she and her daughter Andromeda (ăn-drŏm′-ē-dȧ) were more beautiful than any of the goddesses, and placed the whole family in the sky. *The queen's chair is composed of five brilliant stars that form a W.*

Perseus, near Cassiopeia (Fig. 225), is represented as holding a sword in his right hand, while in his left hand is the head of Medusa. In mythology Perseus is supposed to have beheaded Medusa, whose hair was hissing serpents, and whose features were so hideous as to change into stone every living object upon which she fixed her gaze.

Taurus is represented as a bull in the act of plunging at Orion. *Aldebaran* (al-deb′-a-ran) is the end star on the lower arm of the V-shaped collection of stars in the head of the bull as pictured. It is the red eye of the angry bull, Taurus. Aldebaran gives off 45 times as much light as our sun, and the light requires 32 years to reach us.

The Pleiades (ple′-ya-dees), another part of the constellation of Taurus, were, in mythology, the daughters of Atlas. They prayed to the gods for protection from Orion the hunter. Jupiter placed them in

Northern Hemisphere.
Fig. 225

the sky. Seven stars may quite easily be seen in this group. There are in reality over three thousand. The stars are surrounded by a misty appearance which makes astronomers believe they form a great star system, evolving from a nebula. The stars look close together, but in

reality they are very far apart. It requires several years for light to travel from one of these stars to another and hundreds of years for the light to reach us.

Southern Hemisphere.
Fig. 226.

Pegasus (pĕg'á-sŭs), the flying horse, contains the *Great Square of Pegasus*. The stars at each corner of the square are bright but not large. There are no noticeable stars within the square.

Pegasus was supposed to have sprung from the body of Medusa after her death.

Auriga (ô-rĭ′-gȧ), the charioteer or wagoner, is a constellation the origin of whose name is unknown. **Capella** (kȧ-pĕl′-ȧ), bright as a diamond, is the principal star in this constellation. It is high above Orion toward the north, about half way between Orion and Polaris.

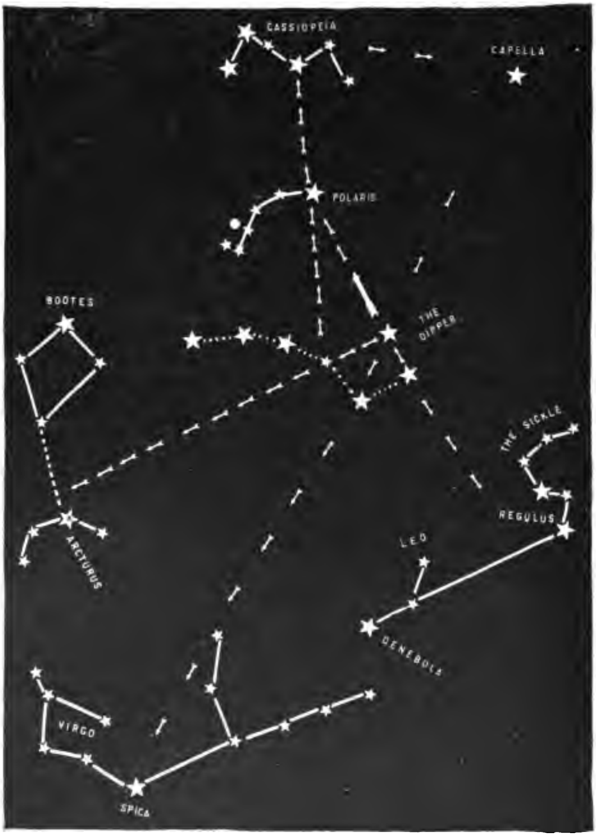


FIG. 227.—The Dipper as an index to the stars.

It has no rival near it. Capella resembles our sun although it is very much larger. It gives off 120 times as much light and about forty years is required for this light to reach us. This star passes almost overhead in the evenings during January and February.

Cetus, the whale, is a huge sea monster.

Pisces (pĭs′-ēz), the fish, is represented by two fish tied together. This constellation consists of small stars, and cannot be seen unless the moon is absent.

Gemini (jĕm′ĭ-nī), the twins, represent twin brothers, *Castor* and *Pollux*.

These two young men were skilled in training horses and boxing, so the myth goes. They accompanied Jason in his search for the golden fleece. Castor was slain, which caused Pollux so much grief that Jupiter placed them in the heavens as immortals. These stars, Castor and Pollux (pŏl′ ŭks), were supposed to exert a benign influence on the ocean; therefore, they were loved by sailors.

The two stars may be easily seen during the winter months passing near the zenith about one hour later than Capella. They are in a part of the sky where there are no other bright stars. Pollux is a yellow star and about the age of our sun, while Castor is white and a young star.

Orion is represented as a hunter attacking Taurus, the bull.

Orion, in the story, was bitten in the heel by Scorpion, because of his boast that he could conquer any animal. Diana placed him among the stars. Sirius and Procyon (prō′ sĭ-ŏn), his dogs, are following him. The Pleiades are flying before him.

Below Orion's belt is *Rigel*, a bluish-white star, a sun blazing with the fires of youth. This star is so far away we cannot measure the distance.

Above the Orion's belt is the beautiful red star *Betelgeuse* (bet-el-guz). It is a very old star, and is growing relatively cold, as the color shows; and therefore is tending toward extinction as a source of light and heat. It is so far away from us that the distance has not been measured with certainty.

Canis Major (Great Dog), and **Canis Minor** (Little Dog) contain respectively a brilliant star: *Sirius*, the dog star, and *Procyon* (prō′-sĭ-ŏn) the little dog star.

Sirius is the most brilliant of all the stars in the sky. It is ever changing its color—blue, rose, white. It is a young star about twenty times the size of our sun. The light from this sun reaches us in about eight years after it starts, as it is one of the stars nearest the earth. The brilliancy of this star is estimated to be 48 times as great as that of our sun.

Procyon is a white star which gives out about eight times as much light as our sun, and the light requires about ten years to reach us.

Leo (li′-on).—This constellation has its principal stars arranged in the form of a sickle. At the end of the handle of the sickle is the glittering white star *Regulus* (rĕg′-u-lŭs). This is a great sun, giving out 1000

FIG. 228.—The Stars during our winter months.

times as much light as our sun. It takes about 160 years for the light to reach us from this giant of the heavens.

Cancer is the crab. In this constellation is a luminous spot called the **Beehive.** An ordinary glass will cause this spot to resolve into stars.

Virgo (vŭr′-gō), in mythology is the virgin, a beautiful maiden with folded wings. *Spica* (spī′kȧ) is the principal star of the constellation *Virgo*. This star is used for determining longitude at sea. It is so far away that the distance has not been measured.

FIG. 229.—The Stars during our summer months.

Hydra is represented by a long straggling serpent. To kill **Hydra** was one of the twelve labors of Hercules as told in the myth.

Canes Venatici (vē-nā′tĭ-cī), a constellation so called because, presumably, supposed to represent hunting dogs.

Berenice's (bĕr'ė-nī'-sēz) **Hair**, a beautiful cluster of stars. Berenice was the wife of Ptolemy (tŏl-ē-mĭ), who was represented as having been sent on a dangerous mission. Berenice consecrated her beautiful tresses to Venus for the safe return of her husband.

Boötes (*the bear driver*) is represented as a huntsman grasping a club in his right hand, while with his left he holds by a leash his two greyhounds. Boötes is supposed to have been Arcus.

Arcturus (ark-tū'-rŭs) is a beautiful bright star in Boötes. The light from this sun is equal to a thousand times that of our sun. Its light reaches us in about 160 years, and it has a diameter of several million miles. In fact this is one of the largest of the suns. It is traveling nearly five miles a second toward the earth. During June and July Arcturus is almost overhead evenings.

Hercules, the great warrior, holds a club in his right hand.

Corona Borealis (bō'rē-ā'-lĭs), the northern crown, consists of six stars arranged in a semi-circular form.

Serpentarius (sŭr'pĕn-tā'rĭ-ŭs), or **Ophiuchus** (ŏf'ĭ-ū'kŭs), is the serpent bearer.

Libra represents the goddess of justice. The constellation may be recognized by the four-sided figure formed by the principal stars.

Scorpio is a huge scorpion. *Scorpio*, so the legend is, sprang from the ground at the call of Juno to sting Orion.

Antares (an-ta'-rees), the principal star of *Scorpio*, is a fiery-red star around which revolves a bright green star. It can best be seen about ten o'clock in the evening during June and July.

Sagittarius (săj-ĭ-tā'-rĭ-ŭs), the archer, holds a bent bow as if ready to let an arrow fly at Scorpio.

The **Southern Fish** has one important star, *Formalhaut*, far down in the south. This star is in the mouth of the fish, of a slight reddish tint, and has no rival in the southern sky. It is used by sailors for navigation.

Cygnus (cyg'nŭs), The Swan, is a group of stars forming the large and beautiful Northern Cross. *Deneb* (den'eb), or *Arided* (ȧ'-rĭ-dĕd'), is in this constellation. It is a very large sun, white in color. It has been estimated it takes 325 years for light to come from this star to us.

Lyra, the harp, contains one brilliant blue star *Vega* (vee-ga), the brightest summer star. It is a very large sun, giving off ninety times as much light as our sun. Light travels to us from Vega in twenty-nine

years. Our whole solar system is moving toward this sun at the rate of thirteen miles per second.

Lyra was the harp upon which Orpheus produced such wonderful music as to cause wild beasts to forget their fierceness, rivers to cease flowing, and the rocks and trees to stand entranced.

Aquila, the Eagle, contains a great sun called *Altair* (ăl-tä'-ĭr) which gives off nearly ten times as much light as our sun. Light from this star reaches us in fifteen years. Northeast of Altair is a diamond-shaped cluster of stars called the **Dolphin.** It is also called **Job's Coffin.**

A moment but to reflect,
  Produces a feeling of wonder and awe:
All things in the Universe,
  Move according to some Divine Law.
Some Force behind it all,
  A Master Force it would seem,
Creates order in the vast unknown,
  And over all reigns supreme.

Questions

1. How many miles an hour is the earth traveling in space (see the table, pages 280-281)?
2. How fast is a building moving with the surface of the earth as the earth rotates?
3. How much faster would a building move on Jupiter?
4. How much would you weigh on Mars? on Jupiter? on Venus?
5. How many miles farther away from the sun is Neptune than the earth?
6. If you are able to lift 100 pounds on earth, how many pounds would you be able to lift on Mars?
7. How many planets the size of Mercury would be required to make a planet as large as the earth?
8. How many earths would be required to make a planet as large as Jupiter?
9. Why does not the sun burn up?
10. How does the sun get its heat?
11. What are some of the superstitions regarding the moon?
12. How can you tell the new moon from the old moon?
13. Why do we have a half moon?
14. What is meant by a full moon?

15. What causes the "man" in the moon?

16. Tell of the moon's effect upon the waters of the oceans.

17. Why do we have higher tides during certain times of the year than at others?

18. Why is the earth flattened at the poles?

19. Why is it necessary to have leap years?

20. Why does a meteor leave a streak of light after it?

21. Why do some meteors come down to earth?

22. Why did the earth become irregular in contour while cooling off?

23. Why do some people believe that Mars is inhabited?

24. How can you determine for yourself whether or not 1920 is a a leap year?

FIG. 230.

The giant star Canopus compared in size to our Sun, the white dot at the bottom of the illustration. Canopus is 239 times larger than our Sun. How much larger is the Sun than our Earth? How much larger is Canopus than the Earth?

CHAPTER XIV

"SAFETY FIRST"

CAUSE AND PREVENTION OF ACCIDENTS

Thinking.—To have "Safety First" constantly in mind is to render first aid to the uninjured; and it renders first aid to the injured unnecessary.

FIG. 231.—When he gets back from the hospital, he will tell about his "accident," and talk about his bad luck.

Many a cripple would still be of sound body, and many a man, killed by accident, would be alive and well, if people had stopped to think. "If I had only stopped to think," is a phrase often used by people who have been injured or have been the cause of some accident.

The Thoughtless Man.—In most cases the man who is always having "hard luck" and getting hurt is the man who is thoughtless about his safety. Such a man may climb a ladder which has not been firmly placed on the ground. He takes a chance, gets hurt, and people say he is always getting injured. "He has such hard luck."

Chance Taking.—"A chance taker is an accident maker." Whenever we hear of people taking chances, and especially unnecessary

chances, we must class them as wrongdoers of a certain type, since they endanger not only their own lives but often the lives of others.

People *will* cross the street in the middle of a block, or they *will* take a chance by crossing a street against traffic and even against the policeman's signal for closed traffic. An automobile driver may try to beat a train to a crossing when the time saved would probably amount to only a few seconds. He may not succeed, and terrible consequences may result.

FIG. 232.—The man who says to the driver: "Let her go," is a menace to the community, for he is reckless of the safety of others.

Caution should not be confounded with fear. The exercise of caution, the habit of consideration of "safety first," need in no manner interfere with work or recreation. There is no rational thing which we desire to do that cannot be done in a manner consistent with the thought of "safety first."

Hurry.—One must not think that speed of accomplishment necessitates hurry. The former is essential and desirable, but the latter is unnecessary, undesirable, and unworthy of a person who organizes his activities so as to obtain the greatest efficiency in the quickest time possible.

Hurried minds and hurrying bodies are not at their best. Nothing done hurriedly is ever done as well as it could have been done. There is little excuse for saying, "I was in such a hurry." That phrase often tells us that the speaker is not doing things in a well-systematized way—thoughtfully, conscientiously, earnestly. To hurry means to waste energy, physical and mental.

This characteristic, hurry, is responsible for most of our accidents. Thought is the cornerstone of conservation and efficiency. Think. Eliminate hurry, worry, carelessness and injury.

Do things well.

Accidents do Not Happen: They are Caused.—What we are in the habit of calling "accidents" can not occur except through lack of thought; the child intent on its play, the adult intent on other matters, is the

FIG. 233.—"Oh, look, look, quick!" What do you think might happen to a driver who is in the habit of looking elsewhere than where his direction lies? The fellow who sits beside the driver is reckless and indifferent to his own safety and that of other people. Thousands of accidents are caused every year through this kind of carelessness.

victim of an "accident." People who give no thought to the danger permit the child to play with a bonfire or matches; permit the child to make the highway a playground, notwithstanding the fact that there are vacant lots, yards, and, in many municipalities, regularly maintained children's playgrounds. The automobile operator, the horse driver, the motorman and the locomotive engineer are too often blamed for injuries received by children when the blame properly rests upon the parent, guardian, teacher or passer-by who failed to point out the dangers. It is possible, by setting a good example, and by repeated words of caution, to train others to think "safety first," and to realize that the chances

taken because of lack of thought, even though they may not result in personal injury or death, are out of all proportion to the pleasure gained or the time saved.

Questions

1. Why should ladders be provided with spikes and be firmly placed on the ground?
2. Why is it better in climbing a ladder to keep the hands on the sides of the ladder rather than on the rungs?
3. Name some common ways of taking chances.
4. What is meant by caution?
5. Name some accidents, and show how they did not *happen*, but were *caused* by thoughtlessness.
6. Why should the driver of an automobile be careful to have two lights on the front of his car?
7. Why are glaring headlights on an automobile dangerous?
8. Why should an automobilist driving with glaring lights, dim the lights, and slow down when approaching another, especially in the country?
9. Why should one always look at a railroad crossing, and listen, besides depending upon bells or the watchman?

DANGERS IN AND ABOUT THE HOME

Accidents about the Home.—The appalling number of accidents happening in and about the homes of America warn us to consider "safety first" there as well. Standing on the arm of a chair or a dilapidated step-ladder to reach the pictures or curtains; neglecting to repair partly broken stair steps; forgetting to light the dark passageway to the cellar; failing to pick up and put aside box lids and other boards which hold protruding nails; failing to repair guards or keep closed the doors over cellar entrances—all of these often result in accidents. Leaving garden or house tools lying on the floor or ground is a small thing, but it shows lack of thought, and very frequently results in damage in and about the home.

Matches and Fire.—Matches should be kept in a metallic box, out of reach of small children. Matches which can be lighted only by striking them on the box are safer and no more expensive than ordinary

matches. Children should never be left alone where they can possibly play with a fire in a fireplace, stove, or elsewhere.

The bonfire burning in a gutter or a vacant lot surrounded by laughing children may be the prelude to much terrible suffering for one or more of the children. Such a thing is indicative of carelessness and lack of thought on the part of the parent, guardian, big brother or sister; and it is evidence of neglect of duty by the passer-by and the police. It ignores "Safety-First." To report to the authorities that children are playing with fire is to show yourself a true citizen, interested in the safety of the community as well as the safety of the children.

1. Give attention to fire prevention; an ounce of prevention is worth a pound of cure.

2. Remember that to have fire prevention in your home is better than to mourn over the loss of property and, possibly, of loved ones.

3. Always be prepared to put fires out before they become dangerous.

4. Always be prepared in case of fire to save every person in your building; *plan before the fire occurs.*

5. Always know where the nearest fire alarm box is situated, and keep the call number of your fire department in plain sight near the telephone.

6. Always call the Fire Department as soon as the fire is discovered.

7. Always see that fire drills are held at least once a week in every school or factory.

8. Always keep your supply of matches in metal boxes throughout the house.

9. Always remember that the flames of the match, improperly, carelessly, thoughtlessly, or wantonly applied, result in the destruction of property, and in death.

10. Always extinguish a lighted match before you throw it away.

11. Always insist on having an outside shut-off attached to your gas supply pipe so that gas may be turned off from the street.

12. Always avoid rubber hose connections for your gas stoves.

13. Always see that all kerosene oil is kept in a closed metal can in a safe place.

14. Always see that all lamps are filled by daylight, burners kept clean and wicks changed often.

FIG. 234.—Don't leave them so: put them away: broken bones and lockjaw have resulted from this.

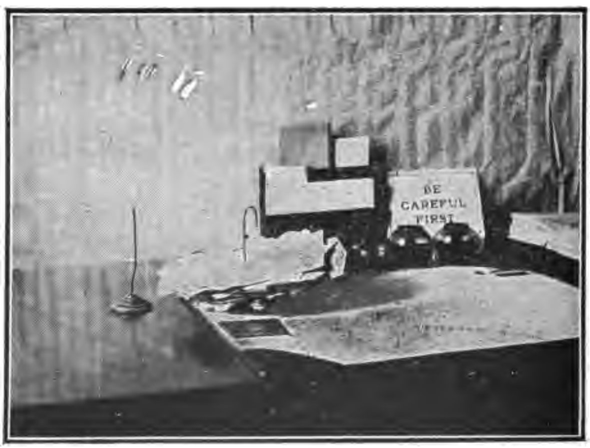


FIG. 235.—Turn down all dangerous points. A slight scratch may result in blood poisoning.

15. Always have your chimneys, stovepipe and stoves examined and cleaned once a year to avoid any danger of fire.

16. Always see that your stove or range is in good condition, and that no spark or live coal can fall on the floor.

17. Always see that all ashes are placed in a metal, tightly closed receptacle.

18. Always keep your buildings clean and free from rubbish, etc.

19. Always have a full pail of water on each floor in the house to put out a starting fire.

20. Always insist on fire-resisting material to cover the roofs of your buildings. A shingle roof is good tinder.

21. Always keep fire escapes in good condition, well painted and clear of all obstructions.

22. Always have your steam boilers examined twice a year.

23. Always have a stationary iron ladder leading to the roof of your building, instead of a movable wooden ladder.

Gas in the Home.—When the odor of gas is detected about the home, the gas must be escaping because a fixture is loose or defective; because some one has only partly turned off the gas; or because the pilot-light for the matchless gas range, or some large gaslight has gone out.

Illuminating gas is inflammable and explosive when mixed with the proper amount of air. *A leak should never be hunted for with a lighted match or candle.* Such carelessness has brought about terrible explosions which have resulted in fires, deaths and much destruction of valuable property. Illuminating gas, as we have already learned in Chapter VI, may cause *asphyxiation.* Gas fixtures should be carefully looked after to see that the stop-cocks turn with some difficulty. Coal stoves generate a dangerous gas similar to illuminating gas. Dampers must be carefully adjusted to allow this gas to escape up the chimney.

Sewer gas may cause sickness and headaches. Tests should be made for leaks in sewer pipes, as described on pages 165, 166.

The Use of Gasoline and Benzine.—Gasoline and benzine are often used for cleaning purposes. We have already learned that the vapor spreads very rapidly when either liquid is exposed to the air. This vapor is very inflammable, and many people have lost their lives by the use of gasoline or benzine without taking proper precautions.

Poisons.—Too many people are careless regarding the labeling and storing of medicines. We often read of deaths caused by some deadly poison taken by mistake because it was in the medicine closet. This shows that every one should have a special place for poisons used to kill flies and mice, or for other purposes. All bottles containing poison should be labeled, with the word **POISON** conspicuous, and kept where children cannot get them, and where adults will not take them by mistake. Medicines which are to be taken internally should never be kept in the same closet with any poisons.

Decomposing Matter.—Decaying matter generates gases that are in most cases dangerous. Food materials easily absorb these gases and thus become unfit for food, and often poisonous for babies and young children. Flies and vermin which carry disease germs to food breed in matter which is decomposing. We should be careful never to leave about the house, yard, alley, or streets any material which will decay, because it may be the means of causing sickness or even death. Have, and use, the garbage pail. Have a tight cover for it. Keep the cover on. Destroy the fly.

Broken Glass or Rusty Nails.—The germs of blood poisoning or lockjaw are introduced into the system through cuts and bruises. Broken glass or rusty nails may be the cause of much suffering. Whenever we see such things lying around, let us make it a point to pick them up and dispose of them in a safe place, to insure the safety of the community.

Electric Wires.—Electric wires which are not well insulated cause fires. We should be sure that all wires which lead to lamps, vacuum cleaners, etc., are well insulated, and are not left near material which would take fire if a short circuit occurred in the wire. When leaving the home for a period of weeks or months, the electricity should be turned off from the house.

Open Holes, Pits, Cellarways, etc.—Many accidents have been caused by leaving manholes open, around which no iron railing has been placed. Cellarways with entrances to the sidewalk should be carefully guarded when open. Only those who are working about manholes and open places in the street should be allowed to stand near them, for frequently plumbers will be found there using their small gasoline furnaces. Children have been hurt or seriously injured by the explosion of

one of these furnaces, or have accidentally overturned the furnace and been terribly burned in the eyes and elsewhere by the molten metal.

Obstacles in the Path.—All boxes, sticks, boards, pipes, wire and other obstacles in the path where people walk should be picked up and removed. Such things may cause very serious injury. Broken knee-caps, ruptured blood vessels in the leg, concussion of the brain, and bad cuts on the face and scalp have been suffered by people who tripped over such material.

Flying Objects.—Care should be taken to see that all tools used have the handles securely fastened on. A hammer head flying from the handle may cause a terrible injury. A loose axe-handle may mean the loss of someone's life. A little attention to these things which are used every day will prevent a great deal of pain and suffering.

Questions

1. What should be done if the stopcock on the gas fixture turns too easily? Why?
2. Why should the gas always be turned off beyond the rubber or silk hose, i. e., turned off at the wall fixture?
3. If an extension cord is used, for an extra light, or a toaster, or other electric appliance, where should the current be turned off when the lamp is not in use? Why?
4. Why should one never hang clothes on the gas fixtures?
5. Why should the windows of the sleeping room always be kept open during the night?
6. Why is it bad to have swinging lamps or gas brackets near a window?
7. Why should a stove have a metal protection on the floor under it?
8. Why is it bad to have a stove pipe in contact with a partition?
9. Why is it a bad practice to put kindling wood in the oven?
10. Why should gasoline, benzine or naphtha never be thrown down a sink, cesspool or sewer?
11. Why should one never leave a lamp burning or a gas light turned down low when no one is in the house?
12. Why should one avoid cleaning clothes with gasoline in a room?
13. What kind of matches is best to use around the home? Why?

14. Why should one never pull a chair from under a person who is just about to sit down?

15. What should be done with all poisons which you may have in the house?

16. Why is decaying matter a source of many diseases?

17. Why are red lights necessary where road mending, or other work, is being done on the road?

18. Why should a clothes-line be placed higher than a person's head, especially on a lawn where people are apt to walk after dark?

19. What injuries may be caused by obstacles such as boards, sticks, and wire lying about the home?

DANGERS OUTSIDE THE HOME

Railroads.—One of the greatest dangers outside the home is the railroad. If we are riding in an automobile and there are no gates for protection at a railroad crossing we are criminally negligent if we do not stop or slow down and *make sure* that there are no trains approaching. We should never try to cross a track when the gates are closed or when the watchman has signaled for us to stop. Walking on the railroad tracks also may cause loss of life or result in a terrible accident which will injure or maim for life.

Boarding and Alighting from Trains.—One should never attempt to alight before the train has come to a full stop. The practice of attempting to overtake a train as it leaves the station and of jumping aboard after the train has started is responsible for many injuries, and always involves great danger.

Street Cars.—In most cases people leave on the right-hand side of street cars. For this reason, one's left hand must be used upon leaving a street car. By using the left hand in alighting from a car, a passenger is always facing the direction in which the street car is moving. A good rule to remember is "The right hand is the right hand for packages and books." Sometimes people enter by the rear of the car, and alight from the front. Unless the car is one whose doors are opened and closed by the motorman, and never when the car is moving, here is a great element of danger, for the person who does not alight properly leaves a car so that his back is toward the direction in which the car is traveling.

If any part of a passenger's clothing catches on the steps and the car starts before it is disengaged, he may be thrown backward, with the possibility of having an arm or leg injured by the wheels. In the case of such accident he will have a greater opportunity to save himself if he is facing the direction in which the car is moving.

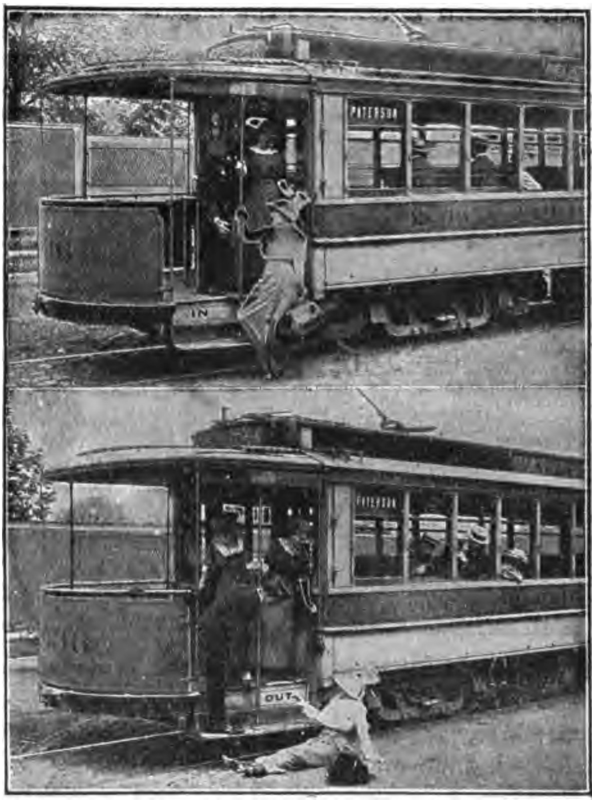


FIG. 236.—When alighting from a car face the direction in which the car is traveling. The top picture shows a woman getting off a car in the wrong way. The result is shown in the bottom picture. The car started before she had both feet on the ground.

Stealing Rides.—A great number of children are killed each year by wagons and cars because of the "stolen ride." A boy riding behind a cart or truck may drop into the street only to be run over by a vehicle following. He may dodge out from behind the car on which he has

stolen a ride only to be struck by an automobile. Some part of the truck may give way, or the tail board may swing down and let two or three boys drop onto the pavement, prospective victims of any oncoming juggernaut.

It is our duty, when we see boys stealing rides on trucks and cars, to inform the drivers in order to protect the lives of the boys. Considerate boys do not place themselves in such dangerous positions—so dangerous as not only to endanger their own lives, but they risk placing the blame for the possible injury or death upon an innocent driver.

Fig. 237.—He paid with his life for a short ride. It was not worth it.

Elevators.—Many accidents occur from carelessness around elevators.—The following are examples:

1. Boy standing at elevator shaft, second floor. As automatic doors were raised, boy looked over door to first floor. Head caught between door and platform of car. Boy decapitated.

2. A man forced open the doors opening into the elevator shaft and evidently looked down the shaft. The descending elevator caught his head, and the operator found the body lying on the floor with the head wedged between wall of shaft and floor of car.

3. The deceased was holding on to elevator with both hands (under floor of car). The elevator was ascending from first floor, in charge of

other persons. The boy lost his hold and fell to basement in elevator pit.

And so on through the list. In many instances, in fact in almost every one, the victims are themselves to blame. Accident 3 especially

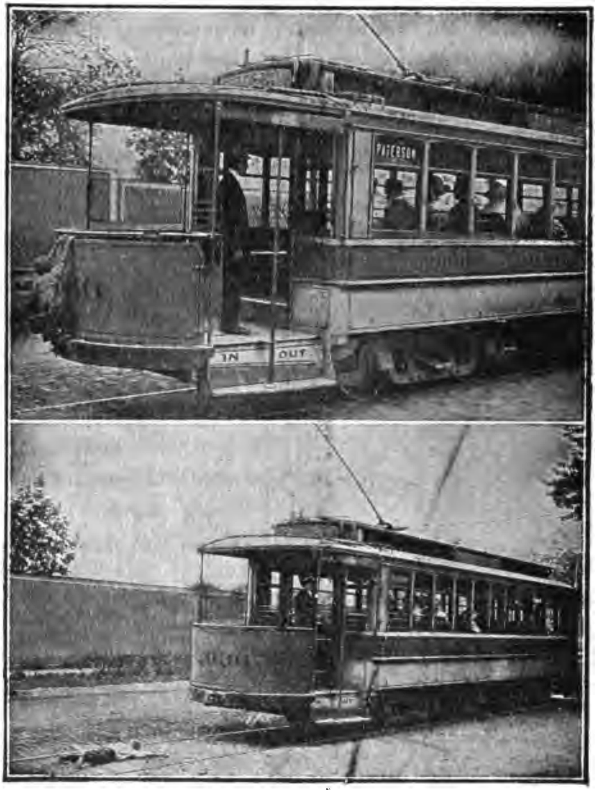


FIG. 238.—Did this ride pay? Who is to blame?

shows the desire to be "smart." This boy was seventeen years old and, as far as can be learned, wanted to do the "original" thing.

Avoid leaning against the elevator door.

Do not attempt to open the elevator door to enter or leave. The operator should attend to this. Never step into the elevator until after the operator has entered.

Shafts, Bolts, Pulleys and Gears.—Some of the accidents causing injury from shafts, pulleys and gears teach a valuable lesson.

These were instances due entirely to thoughtlessness:

1. Internal injuries and broken legs. Caught on a piece of smooth shafting that runs about 2 feet above platform.

2. Back broken. Boy climbing up to revolving shaft, in turning to go back to his work, slipped and was caught by shaft.

FIG. 239.—Call the boy down: Any wire may be "a live wire." Make it your business to prevent a funeral.

3. It is not known whether he was about to step over line shaft or to repair a belt, when he was caught on revolving line shaft. His body struck a pier, and he was dead when first discovered.

4. It is assumed girl was looking for bad shell in back of machine, when, on raising her head, it struck the driving shaft of machine, causing the scalp to be torn completely from her head.

5. One other which fortunately did not prove fatal. She was in the act of combing her hair at the back of the roving frame, supposedly bending over and combing her hair downward, and her hair became caught around the lower back shaft of the frame.

This same accident occurred to two different girls a year apart. The true solution of it is that both girls, in their rush to get out early, stole the company's time for a hasty toilet rather than go to the dressing rooms after dismissal.

6. An accident to a lad of seventeen, no one being able to give a reason for his being where he was. As nearly as can be determined, the boy was trying some experiment with a piece of rope attached to an iron bar. The rope wound around the shaft (which was some 8 feet above the

floor), caused the iron to whirl around and strike him on the head, fracturing the skull. In this instance the shaft appeared so inaccessible as not to need covering, yet the boy managed to get injured by it.

Firearms.—Firearms of all sorts are dangerous. They are made to kill. Children should not be allowed to handle them.

Never point a gun or pistol at any one. It is nearly always the gun or pistol that was *thought to be unloaded* that does the killing.

When several men are out hunting, if they separate, they should have an understanding where each is to go, so that they may not shoot each other.

Be careful about shooting a long-range rifle. The balls from some rifles, when held at a proper angle, carry for several miles.

Boating.—Many lives are lost annually on the water. Both swimming and boating have peculiar dangers of which those who indulge in them should be aware.

A boat is no place to *play* in. Never rock the boat. Never try to exchange seats in deep water. Never stand up when the boat is away from the shore. Do not lean over the side of the boat.

Conclusion.—Conservation is the order of the day, the trend of the times. The most worth while thing is the conservation of health and human life. It is the duty, and should be the pleasure, of all people to aid in this conservation by precept and example, in the home, in the place of business, and on the street. A few words of caution may help the unthinking person to observe "safety first" principles. In *thinking* "safety first" we need not miss any pleasure or leave duty undone; we simply perform our acts without hurry and in the safest possible manner.

The results of the "safety first" policy will be that the boy may grow up to enjoy his manhood and the girl her womanhood; parents will not lose their children in their youth, or be deprived of their companionship and support in old age; adults will not be killed in their prime, and cripples will no longer be the by-products of civilization.

S Steam and street cars.
A Automobiles.
F Fire.
E Electricity.
T Teams, Think.
Y You! the person who must think of "safety first."

"Don't take a chance."

"The right hand is the right hand for bundles."

"Start early. Don't hurry."

"Wait until the car stops."

"Fire is a good servant but a terrible master."

"The 'unloaded' gun frequently kills."

"Trolley and railroad tracks are the giants' sidewalks. You have your own."

"A wire is a dangerous thing; let it alone."

"Gas brackets are not clothes hooks."

"Wait for the fire to kindle, or rebuild it. Don't hurry it with oil."

"Stolen rides often cost too much."

"Play in safe places only."

"Let cars, automobiles, motorcycles, and wagons go past first."

"Work, play, travel; but always think:

"SAFETY FIRST."

FIG. 240.—Mutilated; inefficient. The best safety device is a careful man.

QUESTIONS

1. Why is roller skating dangerous in a street on which there is considerable traffic?

2. Why is it best never to climb poles on which there are wires for the transmission of electric currents?

3. If standing in a wagon or car why should one be careful to hold on to some part of the vehicle when it is about to start?

4. Name some of the dangers and accidents which may occur from riding at the back of wagons, automobiles and cars.

5. Hold books or bundles in the hand in which they should be held while alighting from a car.

6. Why should passengers obey instructions in cars which show the sign, "Do not lean against the door" ?

7. Why should one never put his head or arms out of the window of a moving car?

8. Why should the companion of an automobile driver never call his attention suddenly to anything so out of his line of vision that to see it his head must be turned away from the road?

9. Carbon monoxide is one of the gases from the exhaust of an automobile. Why should one always open the door of a garage before starting the engine?

EMERGENCY TREATMENT *

Emergency Outfit.

One 4-ounce bottle of "Synol soap" or soft-soap liniment.
One 4-ounce bottle saturated solution boric acid.
One 1-ounce bottle flexible collodion.
One 1-ounce bottle 1-1000 solution adrenalin chlorid.
One 2-ounce bottle aromatic spirits of ammonia.
One pair scissors.
Four 1-ounce packages Red Cross absorbent cotton.
Four 1-yard packages sterile Red Cross gauze.
Six 2-inch gauze bandages.
Six 3-inch muslin bandages.
One roll 2-inch adhesive plaster.
One paper medium safety pins.
One hand brush.

* From State Monograph of New Jersey, "The Teaching of Hygiene and Safety."

Note.—Plaster and similar substances seal the wounds on which they are used so that if any pus germs have been introduced they are in the most favorable condition for doing harm. The use of plaster (except court plaster, to cover a trivial scrape not involving the entire thickness of the skin) must be absolutely condemned, for not only does plaster seal the wound, but it is also very likely not to be surgically clean. Collodion is not surgically dirty, like plaster, and as the ether which it contains has some antiseptic properties, it is safer than ordinary plasters, though it also may seal up germs under it.

Slight Cuts (Skin Wound with Slight Bleeding).—Such cuts should be thoroughly cleansed with *soap and hot water*, and the bleeding stopped by steady pressure with a little of the cotton which may be wet with the adrenalin solution. This preparation is of value only in slight superficial bleeding and is useless in severe hemorrhage. If the part cut was not dirty at the time of injury, and the cut was made by a clean instrument or substance, a little of the cotton may now be applied and saturated with collodion, which dries and hardens into a protective covering. This may be hastened by blowing on it. The collodion should not be applied until the bleeding has stopped and the edges of the wound are dry. It should never be used where there is danger of infection from dirt that may have entered the wound. Idoine will kill all germs.

Peroxide of hydrogen should *not* be used if the wound is to be covered.

In the case of scalp wounds the hair should be clipped for half an inch or more around the edges to give opportunity for cleaning and treatment.

Moderate Cut (Deep, or with Free Bleeding.)—Cuts of a more serious depth should have the bleeding stopped by pressure with a small piece of the gauze or the cotton which may if possible be wet with water as hot as can be borne. If this is not available, ice or snow may be used, but *pressure must be the main reliance.* The skin of the part, and the edges of the wound, should be thoroughly washed—scrubbed if possible—with *hot water and soap*, and then a piece of the cotton wet with the boric acid solution applied and retained by a tight bandage, making sufficient pressure to stop the bleeding.

The same treatment should be used for a slight cut made with an unclean instrument. In either case, the wound should be seen by a physician as soon as possible.

Severe Cut.—A cut involving a large artery is recognized by the jet of blood with immediate profuse hemorrhage. In such a case *firm pressure* by the *finger at once* at the point of injury is called for to stop

the bleeding, as otherwise the loss of blood may be so great as to cause collapse, or even death, while other measures are being prepared, even in a minute. The finger thus employed must not be removed till the supply to the artery involved is controlled by the application of a muslin bandage around the arm or leg between the body and the wound, and twisted tight with a stick.* After the bleeding is stopped, the wound may be washed clean as before, dressed with cotton held in place by a bandage, and the patient referred at once to a physician, *who should have been summoned as soon as the injury occurred.*

Nosebleed.—Pack the bleeding nostril with a long twisted piece of the cotton soaked in the adrenalin solution and thick enough to fill the nostril. Keep the patient quiet. Any nosebleed not checked in this way in a few minutes should be referred to a doctor.

Bruises.—To prevent "black eye" or other discoloration in case of bruises, apply a cloth wrung from cold water. The cloth should be continuously applied and *kept cold.*

Burns.—Put the burned hand or finger into cool water to soothe the smarting. Apply a little common baking soda and afterward vaseline, fresh lard or cream.

Particle of Dust, Cinder, etc., in Eye.—When a "foreign body" gets into the eye, the resulting sensation of pain causes an instinctive squeezeing together of the lids, and often a tendency to rub the eye. Very minute particles often cause severe discomfort. If the particle is not sharp, pain may be slight or absent, and the only sensation may be irritation, watering coming on later. If the eye be kept closed and quiet, often the tears will suffice to wash out the offending particle. Never wink or rub the eye, as this may cause scratching and injury to the delicate surface of the eyeball. If the speck is not washed out in this way, separate the lids with the fingers, and search closely, under a bright light, first the inner surface of the lids, then the whites and finally the cornea, or clear part of the eye, for any speck on them.

The inner surface of the upper lid may be readily exposed to view by pulling it downward by the lashes and then turning up over the surface of a pencil. When found, the speck may be removed by wiping with the corner of a handkerchief, or a little cotton wrapped on the end of a match or toothpick. If this does not suffice, no

* A cord or strip, with a stick, thus used corresponds with what is called a *tourniquet.*

further effort should be made to remove it, but the person should be referred to a physician—many eyes are seriously injured and some lost as the result of injury in the attempted removal of such particles by unskilled hands.

Stings.—Remove the sting first either by squeezing or with a knife. Apply wet mud to prevent swelling.

Poison Ivy.—The ivy which is poisonous is that which has three leaves; not the five-leaved. This is found clinging to fences and the stumps of trees in the woods during the spring and summer.

Bathing in buttermilk reduces the fever.

Sweet oil applied heals and soothes.

A mild solution of sugar of lead applied externally kills the poison and prevents spreading.

Knocked "Senseless."—When a person is knocked senseless it may be but a form of fainting, and should be treated in much the same way as an ordinary faint. Lay the person on his back, put something under the shoulders to lower the head that the blood may flow back to the brain, sprinkle cold water on the face.

Unless recovery is prompt and thorough, the person should be seen by a physician, even after recovery, as injuries to skull or brain may not reveal themselves until some hours later.

Hiccoughs.—A single inspiration of the breath caused by a sudden contraction of the diaphragm causes hiccoughs. They may usually be cured by drinking a glass of water. If this is not effective a surprise or shock will often stop them. Holding the tongue will often stop a severe case.

The easiest way to stop ordinary hiccoughing is to *stop hiccoughing*. Sheer will-power—decide *not to hiccough*.

Choking.—First try slapping the back *vigorously*. If that is not effectual lay the child on the floor face downward and continue slapping the back, being sure that the head is a little lower than the rest of the body. If still obstinate take the child by the heels and hold head downward and let some one pound him on the back until the cause of the choking is removed.

Sprains.—When a wrist or an ankle is sprained the ligaments which bind the bones together have been wrenched or torn. Sprains are often more serious than broken bones, and much care must be taken that they

do not result in permanent stiffness. The sprained joint should at once be put into very hot water, and this water should be kept hot for some time. Absolute rest for the leg or arm is then required. Careful rubbing of the sprained joint often shortens the time needed for recovery and very often prevents stiffness.

Dislocation.—When the bone of a joint is forced out of place the ligaments are torn and the muscles are apt to be stretched and irritated, and we say the bone is out of joint. A physician must attend to putting the joint back in place, but meanwhile the patient should be kept quiet. It is well to bind the injured member close to the body, if the injury is of the shoulder or arm; or to tie together the thighs, knees and ankles, if the injury is of the lower extremity.

Broken Bones.—The two ends of the broken bone should be brought together as soon as possible. The doctor should be called at once. In case the patient has to be carried a long distance the ends of the bone might injure the flesh; so it is best to bind the limb close against the body if the injury is of the arm; or to tie together the thighs, knees and ankles, if the injury is of the leg.

Drowning.—When a person is taken out of the water in an apparently drowned condition, there must be no loss of time in attempting to restore breathing. The most practical method of artificial respiration is the one devised by Professor Schaefer, of Edinburgh University. The procedure is as follows:

1. Loosen clothing that may hinder breathing movements of the chest. Turn the patient face down. Wipe out quickly, but as thoroughly as possible, all froth and dirt that may be in the mouth and throat. Force mouth open and pull tongue forward if necessary.

2. Turn patient's face to his right and rest his head upon his bent left arm so that mouth and nostrils are free for air entrance.

3. Then kneel astride, or on one side of the patient's body, facing his head. Place your hands, spread out, on the small of his back with the thumbs parallel and close together pointing toward the patient's head, spread the fingers out on each side of the body over the lowest ribs, then lean forward and, keeping the arms straight, allow the weight of your body to come on to your hands so as to produce a slow *steady pressure* upon the patient's ribs, the object being to press the ribs downward and inward so as to *decrease* the size of the chest cavity and thus

crowd water along with air out from the lungs and air passages. Then swing backward so as to relieve the pressure on the patient's body, but still keep your hands in place; the object being to allow the ribs to spring back and thus *increase* the size of the chest cavity, so as to admit fresh air. Repeat this forward and backward movement, pressure and relaxation of pressure, every four or five seconds. In other words, sway your body regularly forward and backward, as described, twelve or fifteen times a minute without any marked pause between the movements.

Continue this procedure until natural breathing is resumed. There may be no success for a long period; but breathing has been restored by this method when the patient had been *breathless as long as two hours*.

If help is available, hot flannels may be applied to the limbs and body and friction to the hands and feet for the promotion of warmth; but on no account should the regular effort to restore breathing be interrupted *nor should any attempt be made to give restoratives by the mouth* until natural breathing has been established and you have tested very carefully the ability of the patient to swallow.

When the patient begins to breathe, he may be turned on his back and further treatment for promotion of warmth and circulation may be adopted. He should be wrapped in warm blankets or coats, and everything done to restore heat; hot flannels over the abdomen, hot water bottles or any hot objects, properly protected, in the arm pits, at the soles of the feet and so on.

When the patient has regained consciousness and is breathing regularly, a teaspoonful of warm water may be given carefully to see if he can swallow. If the power of swallowing has returned, a small quantity of *hot black coffee*, *beef tea*, or *hot water* may be given. The patient should be put to bed as soon as possible and encouraged to sleep. He should be watched very carefully for some time, so that the treatment may be resumed if the breathing should threaten to fail again.

The advantages of this method of artificial respiration over the older ones are:

1. The ease with which artificial respiration may be performed, hardly any exertion being required.
2. The efficiency with which the exchange of air in the lungs can be produced.
3. The extreme simplicity of the procedure.
4. The impossibility of the air-passages being blocked by the falling back of the tongue.

5. The readiness with which water and mucus are expelled from the air-passages through the mouth and nostrils.

6. It involves no risk of injury to the congested organ or to any other organ.

7. It is very easily remembered, and can be put into operation by one person. *Let everyone memorize it.*

Sunstroke.—1. Lay the person in a shady place.
2. Loosen the clothing.
3. Reduce the heat of the body at once by application of cold water and ice.
4. Send for the doctor at once.
5. *Give no medicine or stimulants,* as the body is already overheated.

Warning-signs of heat prostration are sick stomach, faintness, dizziness; perspiration ceases and skin becomes dry and hot.

Sunstrokes and heat prostrations *may be avoided* by following these rules

1. Keep the general health good.
2. Avoid excesses in eating, drinking, exercise.
3. Avoid use of liquors.
4. Dress according to the season.
5. Drink plenty of cool water.
6. Take plenty of sleep in a well-ventilated room.
7. Avoid constipation.

Clothing on Fire.—Wrap patient in a blanket, rug, cloak or shawl to smother the flames. Roll him and slap the burning parts to put out the flame, and then throw on water. *Smothering the flames* is the best way to put out any small fire.

Fainting.—The fainting person should be laid with head lower than body. Secure fresh air and keep away bystanders. Give a teaspoonful of the aromatic spirits of ammonia in a little cold water, and allow patient to smell from the bottle.

Electric Shock.—A patient rendered unconscious calls for artificial respiration, as after drowning, but it should be continued longer before giving up.

APPENDIX

TABLES OF WEIGHTS AND MEASURES

Preliminary Suggestions

Dry Measure.—The dry measures should be made of metal, or of well-seasoned wood, varnished, with a metal band around the top, or of similar and suitable material. They should preferably be cylindrical. If they are conical, the top diameter should exceed the bottom diameter by an amount not exceeding 10 per cent of the latter.

The *diameters* should in no case be less than those given below:

Measure.	Minimum Diameter. Inches.
½ bushel	13¾
1 peck	10⅞
½ peck	8½
2 quarts	6⅝
1 quart	5⅜
1 pint	4

Linear Measure.—The yard measure should be made of well-dried wood with metal ends, or entirely of metal, or of other material of which the form and dimensions remain reasonably permanent under normal conditions. It should be subdivided into inches and their fractions, and also into the customary fractional subdivisions of the yard, i.e., halves, quarters, eighths, and sixteenths.

The tape should be of steel, or of wire-woven cloth when such construction gives it sufficient strength and permanency. At least 1 yard of this tape should be subdivided as above.

EQUIVALENTS OF EVERY-DAY UNITS USED IN THE KITCHEN

The measures of capacity used in the kitchen are based upon the *standard cup*, as follows:

3 teaspoonfuls	=	1 tablespoonful = 4 drams	1 cupful	=	8 fluid ounces
4 tablespoonfuls	=	$\frac{1}{4}$ cupful = 2 fluid ounces	2 cupfuls	=	16 fluid ounces
$\frac{1}{2}$ cupful	=	1 gill = 4 fluid ounces	16 fluid ounces	=	1 pint
2 gills	=	1 cupful = 8 fluid ounces	4 cupfuls	=	1 quart

In the above table all measures are *level full*. The equivalents given will permit the use of the large glass graduate for measuring liquids in cooking.

TABULATED EQUIVALENTS OF CAPACITY UNITS USED IN THE KITCHEN

Units.	Fluid Drams.	Tea-spoon-fuls.	Table-spoon-fuls.	Fluid Ounces.	$\frac{1}{4}$ Cup-fuls.	Gills ($\frac{1}{2}$ Cup-fuls.)	Cup-fuls.	Liquid Pints.	Liquid Quarts.	Cubic Centi-meters.	Liters.
1 fluid dram equals..............	1	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	$\frac{1}{128}$	$\frac{1}{256}$	3.7	0.004
1 teaspoonful equals............	$1\frac{1}{3}$	1	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{12}$	$\frac{1}{24}$	$\frac{1}{48}$	$\frac{1}{96}$	$\frac{1}{192}$	4.9	0.005
1 tablespoonful equals...........	4	3	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{64}$	15	0.015
1 fluid ounce equals.............	8	6	2	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{32}$	30	0.030
$\frac{1}{4}$ cupful equals.................	16	12	4	2	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$	59	0.059
1 gill ($\frac{1}{2}$ cupful) equals..........	32	24	8	4	2	1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	118	0.118
1 cupful equals.................	64	48	16	8	4	2	1	$\frac{1}{2}$	$\frac{1}{4}$	237	0.237
1 liquid pint equals.............	128	96	32	16	8	4	2	1	$\frac{1}{2}$	473	0.473
1 liquid quart equals............	256	192	64	32	16	8	4	2	1	946	0.946
1 cubic centimeter equals........	0.27	0.20	0.068	0.034	0.017	0.0084	0.0042	0.0021	0.0011	1	$\frac{1}{1000}$
1 liter equals..................	270	203	67.6	33.8	16.9	8.45	4.23	2.11	1.06	1000	1

TABLES OF WEIGHTS AND MEASURES

Apothecaries' Fluid Measure

60 minims	=	1 fluid dram
8 fluid drams	=	1 fluid ounce
16 fluid ounces	=	1 liquid pint
8 liquid pints	=	1 gallon

(British measures differ from above)

Apothecaries' Weight

20 grains	=	1 scruple
3 scruples	=	1 dram
8 drams	=	1 ounce
12 ounces	=	1 pound

Avoirdupois Weight

$27\frac{11}{32}$ grains	=	1 dram
16 drams	=	1 ounce
16 ounces	=	1 pound
25 pounds	=	1 short quarter
28 pounds	=	1 long quarter

4 quarters = 1 hundredweight { short hundredweight = 100 pounds; long hundredweight = 112 pounds }

20 hundredweight = 1 ton { short ton = 2000 pounds; long ton = 2240 pounds }

Circular Measure

60 seconds	=	1 minute
60 minutes	=	1 degree
90 degrees	=	1 quadrant
4 quadrants	=	1 circle or circumference

Cubic Measure

1728 cubic inches	=	1 cubic foot
27 cubic feet	=	1 cubic yard
144 cubic inches	=	1 board foot
128 cubic feet	=	1 cord

Dry Measure

2 pints	=	1 quart
8 quarts	=	1 peck
4 pecks	=	1 bushel

1 barrel (for fruit, vegetables, and other dry commodities) = 7056 cubic inches = 105 dry quarts

Linear Measure

12 inches	=	1 foot
3 feet	=	1 yard
5½ yards	=	1 rod or pole
40 rods	=	1 furlong
8 furlongs	=	1 statute mile (1760 yards, or 5280 feet)
3 miles	=	1 league

Linear Measure (Special)

1000 mils	=	1 inch
72 points	=	1 inch
3 barleycorns	=	1 inch
4 inches	=	1 hand
7.92 inches	=	1 surveyor's link
9 inches	=	1 span
6 feet	=	1 fathom
40 yards	=	1 bolt (cloth)
10 chains	=	1 furlong
6080.20 feet	=	1 nautical mile = 1.1516 statute miles

Liquid Measure

4 gills	=	1 pint
2 pints	=	1 quart
4 quarts	=	1 gallon
31½ gallons	=	1 barrel
2 barrels	=	1 hogshead

Paper Measure

For small papers the old measure is still in use:

24 sheets	=	1 quire
20 quires	=	1 ream (480 sheets)

For papers put up in cases, bundles, or frames the following measure is now used:

25 sheets	=	1 quire
20 quires	=	1 standard ream (500 sheets)

Square Measure

144 square inches	=	1 square foot
9 square feet	=	1 square yard
30¼ square yards	=	1 square rod or perch
160 square rods	=	1 acre
640 acres	=	1 square mile
36 square miles	=	1 township (6 miles square)

Surveyor's Measure

7.92 inches	=	1 link (Gunther's or surveyor's)
100 links	=	1 chain (=60 feet)
80 chains	=	1 mile

Surveyor's Area Measure

625 square links	=	1 (square) pole or square rod
16 (square) poles	=	1 square chain (surveyor's)
10 square chains or 160 square rods	=	1 acre
640 acres	=	1 square mile
36 square miles	=	1 township

Time Measure

60 seconds	=	1 minute
60 minutes	=	1 hour
24 hours	=	1 day
7 days	=	1 week
365 days	=	1 year
366 days	=	1 leap year

Troy Weight

24 grains	=	1 pennyweight
20 pennyweights	=	1 ounce
12 ounces	=	1 pound (troy)
1000 troy grams	=	1 pound—avoirdupois
1 troy or apothecaries' pound	=	5760 grams

Carat (for precious stones) = 200 milligrams. The carat was formerly an ambiguous term having many values in various countries.

Karat (fineness of gold) = $\frac{1}{24}$ (by weight) gold. For example, 24 karats fine = pure gold; 18 karats fine = $\frac{18}{24}$ pure gold.

Mariner's Measure

6 feet	=	1 fathom
120 fathoms	=	1 cable length
7½ cable lengths	=	1 mile
5280 feet	=	1 statute mile
6085 feet	=	1 nautical mile

Miscellaneous

3 inches	=	1 palm
4 inches	=	1 hand
6 inches	=	1 span
18 inches	=	1 cubit
21.8 inches	=	1 Bible cubit
2½ feet	=	1 military pace

International Metric System.—In the international metric system the fundamental unit is the **meter**—the unit of length. From this the units of capacity (**liter**) and of weight (**gram**) were derived. All other units are the decimal subdivisions or multiples of these. These three units are simply related; e.g., for all practical purposes 1 *cubic* decimeter equals 1 liter, and 1 liter of *water* weighs 1 kilogram. The metric tables are formed by combining the words *meter*, *gram*, and *liter* with the six numerical prefixes, as in the following tables:

Prefixes.		Meaning.			Units.	
milli-	=	one thousandth	$\frac{1}{1000}$	0.001	meter	for *length**
centi-	=	one hundredth	$\frac{1}{100}$	.01		
deci-	=	one tenth	$\frac{1}{10}$	.1		
Unit	=	one		1	liter	for *volume* (*capacity*) *
deka-	=	ten		10		
hecto-	=	one hundred		100		
					gram	for *weight* (*mass*) *
kilo-	=	one thousand		1000		

* One meter = 39.37 inches; 1 liter = 1.0567 liquid quarts; 1 gram = 0.035 avoirdupois ounce.

Units of Length.		Units of Capacity.		Units of Weight (or Mass).	
millimeter	0.001 meter	milliliter	0.001 liter	milligram	0.001 gram
centimeter	.01 "	centiliter	.01 "	centigram	.01 "
decimeter	.1 "	deciliter	.1 "	decigram	.1 "
METER	1 "	LITER	1 "	GRAM	1 "
dekameter	10 "	dekaliter	10 "	dekagram	10 "
hectometer	100 "	hectoliter	100 "	hectogram	100 "
kilometer	1000 "	kiloliter	1000 "	kilogram	1000 "

Units of Area.—The table of *areas* is formed by squaring the length measures, as in our common system. For land measure 10 meters square is called an *are* (meaning *area*). The side of one are is about 33 linear feet. The hectare is 100 meters square, and, as its name indicates, is 100 ares (about 2½ acres).

Relative Value.	Length.	Surface.	Capacity.	Solidity.	Weight.
10,000	Myriameter				
1,000......	Kilometer..	....	Kiloliter....	....	Kilogram
100......	Hectometer.	Hectare....	Hectoliter..	....	Hectogram
10......	Dekameter..	....	Dekaliter...	Dekastere..	Dekagram
Unit........	Meter......	Are........	Liter.......	Stere.......	Gram
0.1.........	Decimeter..	Deciare....	Deciliter...	Decistere...	Decigram
0.01........	Centimeter.	Centiare....	Centiliter...	....	Centigram
0.001.......	Millimeter..	....	Milliliter...	....	Milligram

THE FRENCH (METRIC) AND APPROXIMATE EQUIVALENTS OF ENGLISH MEASURES

Linear

1 yard	$\frac{11}{12}$ meter.
11 meters	12 yards
To convert meters into yards	Add $\frac{1}{11}$.
1 meter = 1.1 yd.; 3.3 ft.	3 ft. $3\frac{3}{8}$ inches ($\frac{1}{512}$ less). 40 inches (1.6 per cent less).
1 meter, by the Stand. Commission	= 39.38203 inches.
1 meter, by the Act of 1878	= 39.37079 inches
1 foot	3 decimeters (more exactly 3.048).
1 inch	25 millimeters (more exactly 25.4).
1 mile	1.6 or $1\frac{3}{5}$ km. (more exactly 1.60931).
1 kilometer	$\frac{5}{8}$ of a mile.
1 chain (22 yards)	20 meters (more exactly 20.1165).
5 furlongs (1100 yards)	1 kilometer (more exactly 1.0058).

Area

1 square yard	$\frac{5}{6}$ square meter (more exactly .8361).
1 square meter	$10\frac{3}{4}$ square feet. $1\frac{1}{5}$ square yards.
1 square inch	$6\frac{1}{2}$ square centimeters (more exactly 6.45).
1 square mile (640 acres)	260 hectares (0.4 per cent less)
1 acre (4840 square yards)	4000 square meters (1.2 per cent more).

Volume

1 cubic yard	$\frac{3}{4}$ cubic meter (2 per cent more).
1 cubic meter	$1\frac{1}{3}$ cubic yards ($1\frac{2}{3}$ per cent less).
1 cubic meter	$35\frac{1}{3}$ cubic feet (.05 per cent less)

Weight

1 cubic meter of water	1 long ton nearly.
1 kilogram	2.2 pounds fully.
1000 kilograms 1 metric ton	1 long ton nearly.
1 long hundredweight	51 kilograms nearly.
1 United States hundredweight	$45\frac{1}{2}$ kilograms nearly.

METRIC MEASURES

Measures.		Metric to Customary.			Customary to Metric.		
LENGTHS		1 millimeter	= 0.03937	inch	1 inch	= 25.4001	millimeters
		1 centimeter	= 0.3937	inch	1 inch	= 2.54001	centimeters
		1 meter	= 39.37	inches	1 inch	= 0.0254	meter
		1 meter	= 3.28083	feet	1 foot	= 0.304801	meter
		1 meter	= 1.093611	yards	1 yard	= 0.914402	meter
		1 kilometer	= 0.62137	mile	1 mile	= 1.60935	kilometers
AREAS		1 square millimeter	= 0.00155	square inch	1 square inch	= 645.16	square millimeters
		1 square centimeter	= 0.1550	square inch	1 square inch	= 6.452	square centimeters
		1 square meter	= 10.764	square feet	1 square foot	= 0.0929	square meter
		1 square meter	= 1.1960	square yards	1 square yard	= 0.8361	square meter
		1 square kilometer	= 0.3861	square mile	1 square mile	= 2.5900	square kilometers
		1 hectare	= 2.471	acres	1 acre	= 0.4047	hectare
VOLUMES		1 cubic millimeter	= 0.000061	cubic inch	1 cubic inch	= 16,387.2	cubic millimeters
		1 cubic centimeter	= 0.0610	cubic inch	1 cubic inch	= 16.3872	cubic centimeters
		1 cubic meter	= 35.314	cubic feet	1 cubic foot	= 0.02832	cubic meter
		1 cubic meter	= 1.3079	cubic yards	1 cubic yard	= 0.7645	cubic meter
CAPACITY	*Liquid*	1 liter	= 1.05668	quarts	1 quart	= 0.94636	liter
		1 liter	= 0.26417	gallon	1 gallon	= 3.78543	liters
	Dry	1 liter	= 0.9081	quart	1 quart	= 1.1012	liters
		1 liter	= 0.11351	peck	1 peck	= 8.80982	liters
		1 dekaliter	= 1.1351	pecks	1 peck	= 0.8810	dekaliter
		1 hectoliter	= 2.83774	bushels	1 bushel	= 0.35239	hectoliter
MASSES	*Avoirdupois*	1 gram	= 15.4324	grains	1 grain	= 0.6480	gram
		1 gram	= 0.03527	ounce	1 ounce	= 28.3495	grams
		1 kilogram	= 2.20462	pounds	1 pound	= 0.45359	kilogram
	Troy	1 gram	= 0.03215	ounce	1 ounce	= 31.10348	grams
		1 kilogram	= 2.67923	pounds	1 pound	= 0.37324	kilogram
	Apothecaries'	1 gram	= 0.2705	dram	1 dram	= 3.6967	grams
		1 gram	= 0.8115	scruple	1 scruple	= 1.2322	grams

CONVERSION TABLE

To Change	To	Multiply By
Inches	Centimeters	2.5400
Centimeters	Inches	0.3937
Feet	Meters	0.3048
Meters	Feet	3.2808
Miles	Kilometers	1.6093
Kilometers	Miles	0.6213
Square inches	Square centimeters	6.4520
Square centimeters	Square inches	0.1550
Square feet	Square meters	0.0929
Square meters	Square feet	10.7640
Square yards	Square meters	0.8361
Square meters	Square yards	1.1960
Square miles	Square kilometers	2.5900
Square kilometers	Square miles	0.3861
Cubic inches	Cubic centimerets	16.3872
Cubic centimeters	Cubic inches	0.0610
Cubic yards	Cubic meters	0.7645
Cubic meters	Cubic yards	1.3079
Cubic feet	Liters	28.3170
Liters	Cubic feet	0.0353
Quarts	Liters	0.9463
Liters	Quarts	1.0566
Fluid ounces	Cubic centimeters	29.5740
Cubic centimeters	Fluid ounces	0.0338
Ounces	Grams	28.3495
Grams	Ounces	0.0352
Pounds	Kilograms	0.4535
Kilograms	Pounds	2.2046
Grains	Grams	0.0648
Grams	Grains	15.4324
Pounds weight	Dynes	444520.5800
Dynes	Pounds weight	$.22496 \times 10^{-10}$
Foot pounds	Kilogrammeters	0.1382
Kilogrammeters	Foot pounds	7.2330

Weight of Every-Day Things

A barrel of flour weighs	196 pounds
A barrel of salt weighs	280 pounds
A barrel of beef	200 pounds
A barrel of pork weighs	200 pounds
A barrel of fish weighs	200 pounds
A keg of powder equals	25 pounds
A stone of lead or iron equals	14 pounds
A pig of lead or iron equals	21½ stone
Anthracite coal, broken—a cubic foot averages	54 pounds
A ton, loose, occupies	40–43 cubic feet
Bituminous coal, broken—a cubic foot averages	49 pounds
A ton, loose, occupies	40–48 cubic feet
Cement, hydraulic Rosedale, weighs per bushel	70 pounds
Cement, hydraulic Louisville, weighs per bushel	62 pounds
Cement, hydraulic Portland, weighs per bushel	96 pounds
Gypsum, ground, weighs per bushel	70 pounds
Lime, loose, weighs per bushel	70 pounds
Lime, well shaken, weighs per bushel	80 pounds
Sand, at 98 pounds per cubic foot, weighs per bushel	122½ pounds

18.29 bushels = a ton. 1.181 tons = a cubic yard.

Familiar Facts

To find circumference of a circle multiply diameter by 3.1416.

To find diameter of a circle multiply circumference by .31831.

To find area of a circle multiply square of diameter by .7854.

To find area of a triangle multiply base by one-half perpendicular height.

To find surface of a ball multiply square of diameter by 3.1416.

To find solidity of a sphere multiply cube of diameter by .5236.

What is an " equal square "? Is not its " diameter " the same as a side?

To find cubic inches in a ball multiply cube of diameter by .5236.

Doubling the diameter of a pipe increases its capacity four times.

A gallon of water (U. S. standard) weighs 8 pounds ⅓ ounce, and contains 231 cubic inches.

A cubic foot of water contains 7½ gallons, 1728 cubic inches, and weighs 62½ pounds.

To find the pressure in pounds per square inch of a column of water multiply the height of the column in feet by .434.

Steam rising from water at its boiling point (212 degrees) has a pressure equal to the atmosphere (14.7 pounds to the square inch).

OBJECTS VISIBLE AT SEA LEVEL IN CLEAR WEATHER

The following table shows the distance at sea level at which objects are visible at certain elevations:

Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.
1	1.31	10	4.18	40	8.37	80	11.83
5	2.96	20	5.92	45	8.87	90	12.25
6	3.24	25	6.61	50	9.35	100	13.23
7	3.49	30	7.25	60	10.25	150	16.22
8	3.73	35	7.83	70	11.07	200	18.72

INDEX

G Marconi

SUPPLEMENT ON

WIRELESS

SPACE, MATTER AND ELECTRICITY

What Radio Communication Means.*—Anyone can learn to operate and care for a piece of apparatus without having any real understanding of its underlying principles. All that is required is a certain type of memory, industry and a little common sense. But a person with only this limited amount of knowledge regarding the subject is of limited usefulness and resourcefulness, and cannot advance very far. An understanding, in a general way, of how radio communication is carried on makes our vision of future possibilities broader and adds to our general knowledge of the useful sciences.

In early days all sorts of methods were used for communication. Some of the earlier methods were, beacon fires; reflecting the sun's rays, and flags. However, the best and most rapid is the electrical method. This includes the ordinary wire telegraph and telephone and the wireless or radio apparatus. Without connecting wires, radio messages are sent from one point to another, from ship to ship, to aeroplanes, from land to sea, across the ocean, and from broadcasting stations, where musical programs, speeches, lectures and various other communications are sent out. The future possibilities of radio communication are enormous. Radio is a powerful factor in the education for citizenship. Agricultural reports aid the farmer and indirectly our entire population; weather news protects our ships and crops; musical and educational programs benefit and entertain young and old, sick and well. Radio communication has profoundly modified our business and

* Adapted from The Principles Underlying Radio Communication, Prepared by the Bureau of Standards, Government Printing Office, Washington, D. C., and Signal Corps, U. S. Army. War Department Document No. 1069. This is an excellent book and may be obtained from the government printing office for one dollar.

social life. Great men send out inspiring messages to millions; children hear bed-time stories; the pulpit speaks to untold masses; and that which is best in the world comes forth to inspire and enlighten. Science has come a little closer to our ordinary walks of life. It is becoming less and less a mystery, and more and more a living reality, a potent force, which will make us better understand ourselves, and the universe in which we exist.

When a pebble is thrown into the smooth water of a pond it starts a series of circular ripples or waves, which spread out indefinitely with a speed of a fractional part of a foot per second. An electrical disturbance starts electrical waves, which spread out in all directions, and travel with the velocity of light, which is 300,000,000 meters per second, or about 186,300 miles per second. It is by means of these electrical waves that radio is sent.

In order to make use of electrical waves for the practical purpose of sending messages, it is necessary:

(A) To produce in a circuit, electrical disturbances which start the waves.

(B) To get the waves, by means of an aerial, out into the surrounding space through which they travel with great speed.

(C) To have the waves strike something at the receiving station (usually another aerial), in which electrical currents will be started by the waves.

(D) To change these electrical currents by instruments so that they may be detected and the message understood.

In order to understand the principles governing the sending and receiving of these messages, it is first necessary to know something of electricity, space and electrons.

Theory of the Universe.—Until recently our universe was thought to be made up of three fundamentals—matter, ether, and energy To-day we believe that science may yet discover that these three are all one and the same thing;* simply different phases of the essential oneness of the universe. It is possible to conceive our world as existing in four dimensions,† three dimensions of space, namely; up and down, backward and forward, right and left, with time as the fourth dimension.‡ Space is

* Prof. J. Arthur Thompson. † Dr. Albert Einstein, Relativity.
‡ T. Royds, Kodaikanal Observatory, India.

now said to have four dimensions of which time is the fourth, and there are still other dimensions.*

If I wish to give a complete dimensional description of myself in my four dimensions, I must give my length, my breadth and my thickness ever since I came into being, and also the course I have traversed through space since that time. This latter distance may be expressed in terms of a unit whose length is 186,000 miles the distance traversed by light in one second. The distance which I travel through space annually is enormous, and very complex as to direction. It involves not merely my own motions as I cross the room, or take a train or steamer, but also those due to the rotation of the earth on its axis, its revolution round the sun, and the motion of the latter through the heavens. In general I travel, or in other words increase my length in the fourth dimension, by over 4000 units a year. The fourth dimension accordingly, if this view is accepted, is simply a distance like the other three, and perfectly easy to understand.

Ether Theory Abandoned.—The most modern science has practically abandoned the theory that the whole world is enveloped in a vast invisible medium called Ether, which fills all space, as a separate and distinct thing. This theory of ether was evolved as an explanation of the flow of energy across space, and the known facts about the traveling of light. Ether was conceived as an elastic medium of great density, extending throughout all the universe. Solid matter could pass through it as though it did not exist, and it filled all space and all matter.

Ether and Einstein's Theory of Relativity.—If ether does really exist, with our earth moving through it, there should be some way of detecting it. Just as we feel a wind when we ride in a fast automobile, so the scientists with their wonderfully refined and delicate instruments should be able to detect some motion in the stream of ether passing our earth, which is speeding so rapidly around the sun. But the most elaborate experimental research has failed to discover any motion through the ether. A great scientist and mathematician, Albert Einstein, has now given us the principle of relativity, viz.: that there is no way of detecting motion through the ether; or in other words, that all motion is relative. He has changed our whole conception of time and space, and our usual idea of ether must be abandoned.

*Prof. William H. Pickering

† Prof. William H. Pickering, Harvard College Observatory, Mandeville, Jamaica.

Unfortunately a precise statement of Einstein's conclusions can only be given in mathematical language. The primary principle * of relativity may be expressed in the form that the world goes on as though no ether existed. † Relativity teaches that the velocity of light is always the same whether the observer be approaching or receding from the source of the light. This is contrary to all former ideas of the ether as previously conceived. Whether any new ether will be devised to replace the old cannot as yet be said but none appears to be necessary.

The Principle of Relativity.—The principle that all motion is relative has been hard for the average person to understand. It is made somewhat simpler, perhaps, by a few examples, illustrating relativity. For instance, an express train, with a speed of 60 miles an hour, is going 60 miles an hour with respect to the earth, and all things standing motionless on the earth. But suppose an automobile were racing on a road beside the track, at exactly the same speed as the train. Then the train and the automobile are not moving at all, with respect to each other. If the train passed a man walking at the rate of 2 miles per hour, it would be going 58 miles per hour, with respect to the man. If the train passed another train going 50 miles an hour in the opposite direction, the two trains would be moving 110 miles per hour, with respect to each other.

If there were only one body in the whole universe, there would be no motion, because there would be nothing to compare speed with. In other words, there could be no "speed." One body alone could not have motion. If there were two bodies capable of motion in the universe, each would then have motion, with respect to the other, and the velocity of the motion of one would depend entirely on the speed at which it was passing, approaching, traveling away from, or around the other body. Our idea of motion is purely relative; we consider the motion with respect to something else.

The Impossibility of Ether.—This theory of relativity destroys the old theory of ether. "If ether fills all space, then there must be absolute position and absolute motion. A body is at rest or is moving relative to the ether, and this would be an absolute motion and would enable us to find out whether the body is standing still in regard to the ether or whether it is moving in regard to the ether, even if no other body

* Postulate.

† James H. Jeans, LL.D., F.R.S. Enc. Brit., Vol. 32, p. 267.

existed."* Moreover, it has been shown that light is a transverse wave. Transverse waves were supposed to exist only in solid bodies. Ether, therefore, should be a solid.

But ether, if it exists, *must* be of extreme tenuity or rareness, since all the cosmic bodies move through it without friction. In the case of the earth, for instance, friction would be shown by an increase in the length of the year, and an increase of the solar distance. But nothing like this has been noticed.

Thus, by reducing the ether theory to an absurdity, we come to the definite conclusion that there is no such thing as ether, and that light waves and wireless waves are not wave motions of ether. But the wave theory of light and other radiations has not been shaken. The question then is: what is the mechanism of the light waves, and the **electromagnetic wave?**

Fields of Force.—We know that a magnet attracts, or exerts force on a piece of iron brought near it. We call the space around the magnet

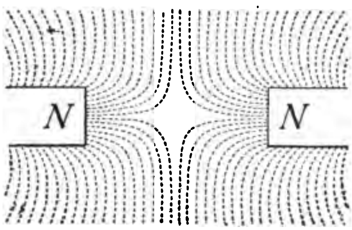


FIG. 1.—A magnet radiates into space a field of force. Two magnets with the positive ends (N and N) toward and near each other radiate fields of forces which repel each other. The lines of force show the repelling effect.

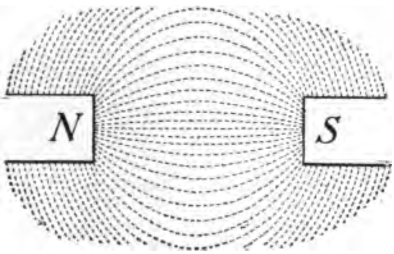


FIG. 2.—Two magnets which have their positive end (N) and negative end (S) toward and near each other radiate into space fields of forces that attract each other. The lines of force show the attracting effect.

a magnetic field. A magnetic field, or **field of force** is "**a condition in space, exerting a force on a body susceptible to this field.**" To produce a field of force requires energy, and this energy is stored in the space we call the field.

* Dr. Charles P. Steinmetz.

There are other kinds of fields of force besides the magnetic. For instance, the earth is surrounded by a **gravitational field.** The space surrounding a wire that carries an electric current is an **electromagnetic field**—a combination of a **magnetic field and an electrostatic field.**

The idea of the field of force, or better, the idea of the field of energy, thus takes the place of the theory of ether. Light, it has been proved, is an electromagnetic wave, and " the beam of light, the wireless wave, **any electromagnetic wave, is a periodic alternation, vibration, or oscillation of the electromagnetic energy field in space."*** The differences in the waves are due to differences of frequency; that is different kinds of electromagnetic waves have a different number of vibrations or oscillations per second.

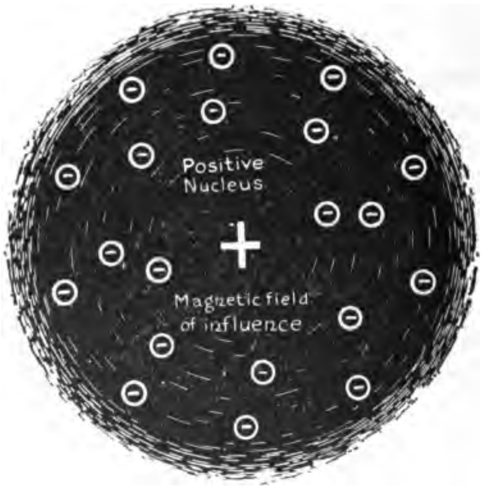


FIG. 3.—A diagram to show the arrangement of electrons outside the nucleus of an atom containing twenty electrons outside the nucleus.
There are ten electrons in the outer circle, eight in the middle circle and two in the inner circle. The electrons in an atom are arranged systematically according to the number of electrons in the atom.
When electrons escape from atoms so as to produce a constant stream of them jumping from atom to atom an electrical current is formed.

The Electron Theory.—The electron (outside the nucleus), is the negative electricity in an atom.

* Dr. Charles P. Steinmetz.

Every particle of matter is supposed to consist of many atoms, and it is thought that all these atoms are composed of negative and positive electricity. In each atom is a nucleus charged with positive electricity. The negative electricity in the atom exists in the form of minute corpuscles or electrons, as they are called, which are continually rotating or vibrating about the positive nucleus, and at a definite distance from it, in much the same way as that in which the earth revolves about the sun. It has been suggested as a possible theory that the two kinds of electricity, positive and negative, are right-handed and left-handed vortices or whirlpools in the ether. The electrons with their plus or positive nuclei make up the atoms; the atoms compose molecules; and the molecules make up the substances of which everything is made,—

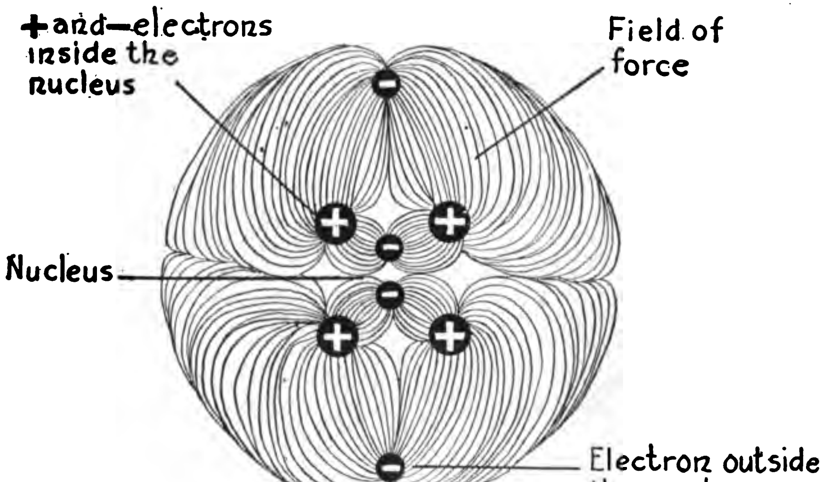


FIG. 4.—A diagram to show that the nucleus of an atom is made up of positive and negative electrons. The positive electrons are 1846 times heavier than the negative but the charges are exactly equal to the negative electrons. There is always a greater number of positive electrons in the nucleus than negative electrons.

the sun, the moon, the earth, human beings, animals, the food we eat; and, in fact, everything in the whole universe.

"If we want to know something of the birth of matter, the decay of matter, the nature of matter, of the nature of electricity, and the rela-

tion of electricity to matter, of the nature of the sun and the sun's rays, of the possible cause of gravitation, the cause of clouds and rain, and the possible solution of many another mystery—if we wish to know something of all this, the electron * is our friend." †

Elements Differ.—The different atoms in each element have a different number of electrons; for example, hydrogen is supposed to contain one electron revolving rapidly around its positive nucleus; helium has two negative electrons; lithium has three; oxygen has eight, and an atom of gold has many electrons, and so has an atom of sulphur. Recently some scientists have advanced the additional theory that these electrons are not actually revolving about the positive nucleus, but are simply in a state of violent agitation at a certain distance from the positive nucleus.

The electrons outside of the nucleus are the negative electrons or the negative charges of an atom which are radiated or thrown off from

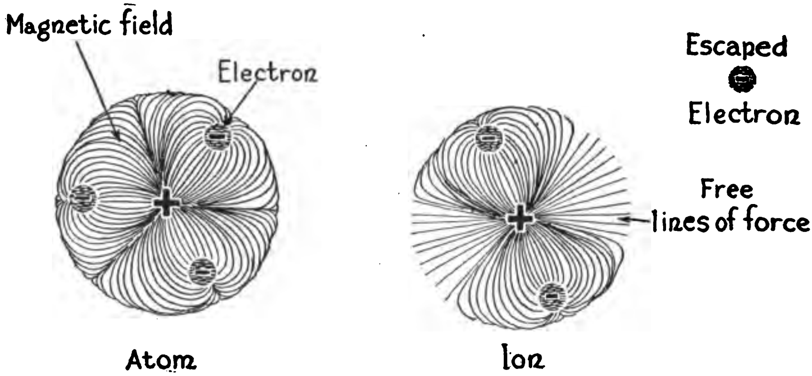


FIG. 5.—A diagram to illustrate the condition of an atom before and after the negative electron has been radiated off. As soon as an atom loses some of its electrons it is called an ion. These ions have positive charges which attract other electrons since there is an excess of unused lines of force from the positive nucleus.

the atom. In reality it is believed that the atom is composed of negative and positive electrons. For example the hydrogen atom has one negative electron outside of the nucleus and one positive electron within

* Corpuscle. † Prof. R. K. Duncan.

the nucleus. The positive electron in the nucleus is 1846 times heavier than the negative electron, but the electrical charge of the positive electron is just equal to the electrical charge of the negative electron. In most atoms both positive electrons and negative electrons are grouped together in a nucleus, and about this nucleus are grouped other **negative electrons** which **may be separated** from the atom. The electrons within the nucleus cannot be separated from the atom. The following table shows how the atoms of a few substances have their electrons arranged:

Element	Atomic Number	Atomic Weight	Positive Electrons in Nucleus.	Negative Electrons in Nucleus.	Negative Electrons Outside Nucleus.
Hydrogen	1	1.007	1	0	1
Helium	2	4	4	2	2
Lithium	3	6 7	6 7	3 4	3 3
Boron	5	10 11	10 11	5 6	5 5
Carbon	6	12	12	6	6
Nitrogen	7	14.01	14	7	7
Oxygen	8	16	16	8	8
Neon	10	20 21 22	20 21 22	10 11 12	10 10 10
Mercury	80	197 198 199 200 202 204	197 198 199 200 202 204	117 118 119 120 122 124	80 80 80 80 80 80

[1] From Recent Discoveries and Theories Relating to the Structure of Matter, by Karl Taylor Compton, Professor of Physics in Princeton University, June, 1922.

The several different atomic weights of such substances as **neon** and **mercury** given in the table refer to the atoms of the same substance which have different masses. These atoms are called **isotopes.** Chlorine atoms for example have weights of exactly 35, 37, and 39 and these different atoms (same substance) or isotopes are always found together in such a proportion that when their weights are averaged it gives 35.46. These weights refer to a standard unit taken which is almost the weight of Hydrogen but is less by .0077 of the unit. This unit is exactly one-twelfth the weight of the carbon atom, one-sixteenth the weight of the ogygen atom, etc.

More important still, it has been shown that all atoms are themselves built out of still smaller and more fundamental units of matter, electrically charged, called positive electrons and negative electrons. There is very decisive evidence of the existence of these two fundamental types of matter, and of the number of each type in any given kind of atom. To this extent, the "electron theory of matter" is no longer to be considered as a theory, but as a fact. *

What Matter Is.—Electrons are so named because they are entirely made up of electricity, so far as is known, and the theory of electrons may be stated in this way: all matter, whatever it may be, is nothing but a manifestation of electricity.

Shape of Electron.—" In attempting to form a mental picture of the electron, it is best not to associate in the mind the idea of a small particle having definite size and mass, in the ordinary sense, because the size and mass of an electron are things about which we must speak somewhat reservedly. The electron manifests itself only in virtue of the electric and magnetic fields created by its presence in the surrounding medium, but whether or not its mass is entirely electromagnetic is as yet an open question."†

Size of Electron.—Electrons are tiny beyond our imaginings. If an orange four inches in diameter were enlarged to the same diameter as the earth, a negative electron (similarly enlarged), if it had definite shape and size, would still be too small to be seen. (1/100,000 inch in diameter.)

* Dr. Karl Taylor Compton.

† H. J. Van Der Bijl.

" Furthermore, the theory of Abraham and Lorentz, for example, leads to the conception of two masses for the electron, namely the so-called transverse and longitudinal masses. As regards the size of the electron, although an estimate has been made of what might be considered its effective radius, by the simple process of integrating the energy of the field, due to the slow-moving electron, it is not unlikely that this represents only one size obtained under one particular set of conditions."
H. J. Van Der Bijl.

If an electron, vibrating in an atom of hydrogen, were so enlarged as to have a diameter of one inch, the atom, proportionately enlarged, would have a diameter of nearly 8000 feet, or about $1\frac{1}{2}$ miles.

If an electron were enlarged to the size of an air-rifle B.B. shot, the size of the black dot, the shot itself, if remaining in proportionate size to the electron, would have to be enlarged to a diameter of 720 times that of the earth, or over seven times the diameter of the sun. The circumference of the shot would be 18,000,000 miles. It would

B.B. Shot
Actual size

FIG. 6.—If a B. B. shot were enlarged to the size of the world one of the electrons in an atom in the shot would be too small to be seen, being only about $\frac{1}{100000}$ of an inch in diameter. If an electron were enlarged to the size of the shot the shot itself would need to be enlarged to 720 times the size of the earth to remain in the same proportion.

take an aeroplane, going 100 miles an hour, ten hours a day every day but Sunday, 60 years to travel around such a body.

Where Electrons are Found.—Electrons are found in everything,—the food we eat, the clothes we wear, the automobiles we ride in, the sugar and salt with which we season our food,—nothing exists without them. "The soil and the water of the earth emit them, and the air we breathe contains them."* In salt, the tiny electrons are coming from the surface of every particle at the enormous velocity of over 100,000 miles per second, a speed which would take them around the earth about five times in one second. Electrons pass straight through opaque bodies and are affected only by the density of the body. Electrons make the air a conductor of electricity; they cause clouds to form in moist air; they affect photographic plates in a dark place, and they make bodies which are struck by them glow in the dark. The sun is sending out countless numbers of electrons into space, some of which reach the earth, and cause various electrical phenomena. Sun spots are said to be vast whirlpools of electrons which affect the magnetism of the earth.

* Prof. R. K. Duncan.

Speed and Power of Electrons.—Electrons can be made to remain free from their atoms only when they are traveling over 3,000,000 feet per second, or about 600 miles. Electrons sometimes travel with the enormous speed of from 10,000 to over 100,000 miles per second. Professor LeBon has calculated that to give a bullet the speed of an electron, it would take 1,340,000 barrels of gunpowder. He declares that there is energy equal to eighty million horse-power stored in a small French copper coin. In the very ink that prints these pages there is more energy than we have yet been able to extract from millions of tons of coal. It is hoped that some day we may know how to reach this enormous energy of the atoms, and use it. If we do, our coal mines will become useless. The whole world will be transformed when we are able to harness the energy in the atom. A small block of wood contains more energy than is now available from a big coal field in Pennsylvania.

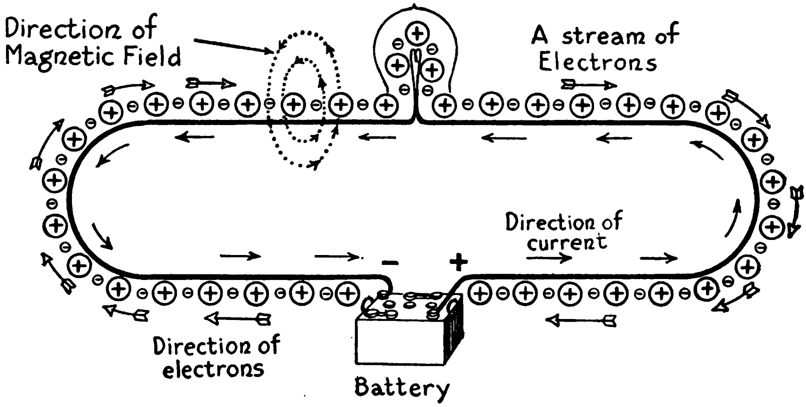


FIG. 7.—A diagram to illustrate the action of the electrons jumping from atom to atom as they form a current of electricity on a wire.

What Electricity Is.—An electric current is supposed to be a movement of electrons from atom to atom. The electrons are supposed not to flow in a body, but to flow from one atom to another. An electron flows from one atom to the neighboring atom, and the neighboring atom sends off one of its electrons to another atom, which, in turn, sends off an electron. Perhaps it would be more nearly accurate to say that

the electrons pass along by jumping from atom to atom with enormous speed. This flow of electrons is a flow of electricity.

Conductors and Insulators.—Some substances contain atoms which part with their electrons easily. These substances are called good conductors of electricity. Copper is an excellent example of a metal containing atoms which give up their electrons readily. The atoms of glass, vulcanite, and porcelain do not give up their electrons very easily. For this reason, electricity will not flow easily in these substances; hence they are called poor conductors of electricity, but very good insulators.

An atom is said to be in a neutral state when the negative electricity exactly neutralizes the effects of the positive electricity. The positive electricity in an atom cannot be taken from the atom, but the electrons (the minus or negative electricity) are constantly getting loose from their atoms, and entering other atoms.

Positively and Negatively Charged Bodies.—If the electrons are driven off from any conductor, the conductor is said to be positively charged; that is, it has an excess of plus or positive electricity in it. If any conductor contains an excess of electrons, it is said to be negatively charged. In other words, a positively electrified body is one whose atoms have lost some of their outlying electrons, so that the positive charge or nucleus predominates. The negatively electrified body has more than enough electrons to balance the positive nucleus.

Electric Current.—According to the electron theory, a current of electricity is a stream of electrons guided by a conductor. This stream or motion is called a **Drift**. It should be remembered that the direction of the stream of electrons or the drift is in the opposite direction from that in which electricity is said to "flow," which was fixed before the electron theory was established.

In a metal conductor many of the electrons are so loosely bound that they are easily set in motion by electric forces. The electrons are supposed to be moving at random, in every direction, with great velocity, even when no voltage is impressed on the conductor. Their velocity can be easily increased. One way of doing this is to apply heat. When the conductor becomes hot enough, electrons are driven off from the surface of any metal conductor. When they are subjected to the influence of an electro-motive force, or difference in potential called

voltage, the random motion of the electrons is controlled, and the random motion gives place to a direct motion or **Drift** which is called an **Electric Current.**

Electromagnetic Energy.—As electrons pass from atom to atom along a wire, they cause a disturbance around the wire which is called a magnetic field. In other words, the surrounding space is filled with energy which is called **electromagnetic energy.**

How an Electric Current is Generated.—Dynamos are used to generate currents of electricity. Coils of wire are rotated rapidly in the

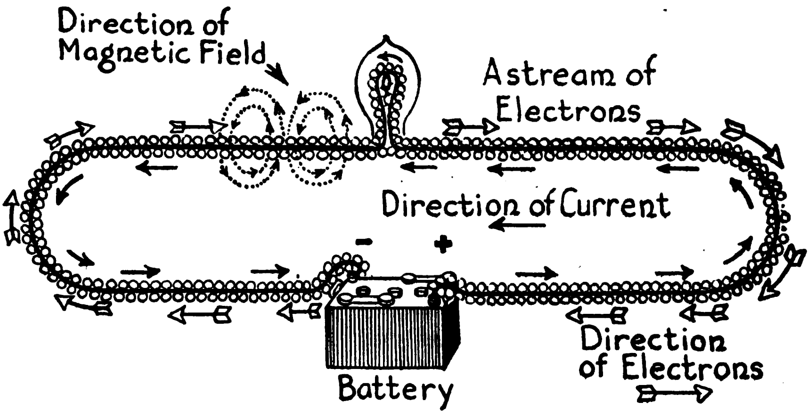


Fig. 8.—A diagram to illustrate the stream of electrons that produce an electric current and the magnetic field about the current.

magnetic field of an electromagnet. When the coils of wire pass through the magnetic field in one direction, the atoms in the wires of the coil give up their electrons, which at once begin to jump from atom to atom. When the coil of wire passes through the magnetic field, in the opposite direction the electrons jump or flow in the opposite direction. This causes an **alternating current.** A **direct current** means a steady flow or drift of electrons from atom to atom in one direction; while an alternating current is a flow of electrons from atom to atom, first in one direction and then in the opposite direction.

Electrical Sparks and Lightning.—When a vast number of electrons jump from one body to another, an electrical spark or flash is produced.

Lightning is probably caused in part by the huge number of electrons which are constantly reaching the earth from the sun. In the upper atmosphere the solar electrons tend to separate and keep apart the positive ions and the negative **electrons.** **Ions** are atoms which have lost some of their negative electrons. Atoms of water vapor constantly rising from the sea and land gather more freely around the positively electrified ions, and bring them down with the rain to the earth. The upper atmosphere becomes charged with the negative electricity or electrons. There arç also some clouds which have a great excess of electrons, and some clouds that have a deficiency. As more and more electrons gather, the tension grows so great that finally there is a violent or explosive rush of electrons. This huge electric spark is called a flash of lightning.

Questions

1. What are the different ways of communication which people use to-day?
2. What method of communication do you consider best? Why?
3. How are you benefited by radio broadcasting?
4. Why should the ether theory be abandoned?
5. If you and a ball in your hand were the only two bodies in space and you let go of the ball what would become of it?
6. If you were riding in a fast-moving train and dropped a rock from it what direction would the rock take with respect to yourself. What direction would the rock take with respect to the earth?
7. Suppose the train in the above question were traveling at the rate of sixty miles per hour. How fast would the rock be going with respect to the train as you held it in your hand? How fast would the rock be going with respect to you? How fast would the rock be going with respect to the earth?
8. Why does a magnet attract iron when the iron is within certain distances of the magnet?
9. What makes the difference in gold, silver, iron, etc.?
10. Why does your hair sometimes snap and crackle on a cold day when you are combing it?
11. What causes the electric lights in your home to give light?

Speed and Character of Radio Wave.—The Einstein theory, as has been stated, has recently upset the idea of the existence of a substance called ether that fills all space, even a vacuum. Certain astronomical experiments, lately performed, seem to confirm the Einstein theory, and prove the non-existence of such a theoretical substance as ether. Until this new theory was put forth, radio waves were explained as vibrations

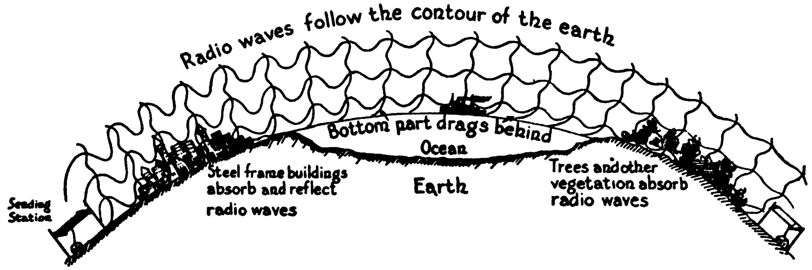


FIG. 9.—A diagram showing our present idea of how waves travel. Tesla has always maintained that radio waves do not travel above the earth, following the curvature of the earth, but rather go through the ground. He has steadfastly maintained that all radio waves pass through the earth and water and that if we must have an aerial, the latter acts as a condenser. The day is coming when no aerial will be used.

in the ether. It is believed, however, that in general they are propagated or radiated through the layer of atmosphere, thirty or forty miles thick, which envelops the earth.*

The speed of these waves is 186,000 miles per second, or about seven and one-half times around the earth in one second. This is the speed of light. Light waves have **frequency** of from 400 to 750 billion **vibrations** per second, while the frequencies of the radio waves vary from less than a half million to about 230 billion vibrations per second.

* Dr. John H. Morecroft, Columbia University.

Frequencies.—The word **frequency** means the number of times a body or wave vibrates, or swings to and fro per second. The term **cycles** per second is often used to express this frequency. The average human ear cannot hear sound from any body producing a wave which has a frequency of less than twenty cycles or vibrations, or more than ten thousand cycles, per second. Some of the notes of a cricket are above 10,000 vibrations per second. Few people can hear these notes. Frequencies below about **10,000 cycles** per second are called **audio frequencies,** because these waves will affect the average human ear causing sounds that can be heard, and frequencies above 10,000 cycles per second which do not affect the human ear are called **radio frequencies.**

The length of light waves is often less than a billionth part of an inch, while wireless waves vary in length from a few feet to over a mile, according to the length of the wave being sent out.

32 vibrations per second produces the lowest musical sound.
128 vibrations per second produces man's conversational voice.
512 vibrations per second produces woman's conversational voice.
2,000 vibrations per second produces high soprano.
4,000 vibrations per second produces the highest musical tones.
40,000 vibrations per second produces the highest audible sound.

Electromagnetic Waves.—The waves used for radio communication are only a particular kind of light wave. They are called **Electromagnetic waves** or **Invisible light waves.** All light really consists of electromagnetic waves. Light waves travel in spheres of electric and magnetic forces at right angles to each other. Light waves of some kind are always present wherever there is an electrical charge vibrating. Whenever current moves back and forth on a conductor, light waves or electromagnetic waves are produced, usually invisible. Several varieties of the electromagnetic waves are already known, and more will probably be discovered.

Length and Frequency of Some of the Radio Waves.*—The radio wave used for communication is usually longer than 150 feet (50 meters). Waves as short as 20 or 40 feet have been used for special work but the shortest waves commonly used to-day are those about 200 meters or

* Marconi has been able to direct a beam of short radio wave of a meter's length or less in any direction desired by means of a reflector. Audible speech has been transmitted over quite a distance with one-meter wave lengths.

about 650 feet in length. (A meter equals 3.28083 feet.) The frequency of these waves is not less than 1,500,000 cycles, **vibrations,** or **oscillations** per second. This is expressed as 1,500 **kilocycles** per second. Commercial radio work begins with a wave about 300 meters or about 1000 feet in length. The waves used for broadcasting in the United States are 360 meters (about 1150 feet) in length, with a frequency of 833,000 cycles, and 485 meters, with a frequency of 618,000 cycles or vibrations per second.

List of Some of the Electromagnetic Waves.—Some of the electromagnetic waves known are:

RANGES OF FREQUENCIES OF VARIOUS KINDS OF ELECTRIC WAVES

		Wave Length.	Frequency Cycles per Second.
Electricity	X-Rays	0.000,000,01 cm. 0.000,000,08 cm.	3,000,000,000,000,000,000 400,000,000,000,000,000
Optics	Ultra-violet radiation	0.000,01 cm.	3,000,000,000,000,000
	Visible light	0.000,04 cm. 0.000,08 cm.	800,000,000,000,000 400,000,000,000,000
	Infra-red radiation	0.02 cm.	1,500,000,000,000
Electricity	Hertzian waves	0.2 cm.	150,000,000,000
	Radio waves	30 meters	10,000,000
	Telephony	30,000 meters	10,000
	Elec. power transmission	3,000 km. 15,000 km.	100 20

* Bureau of Standards, Radio Laboratory, January 21, 1922. Washington, D. C.

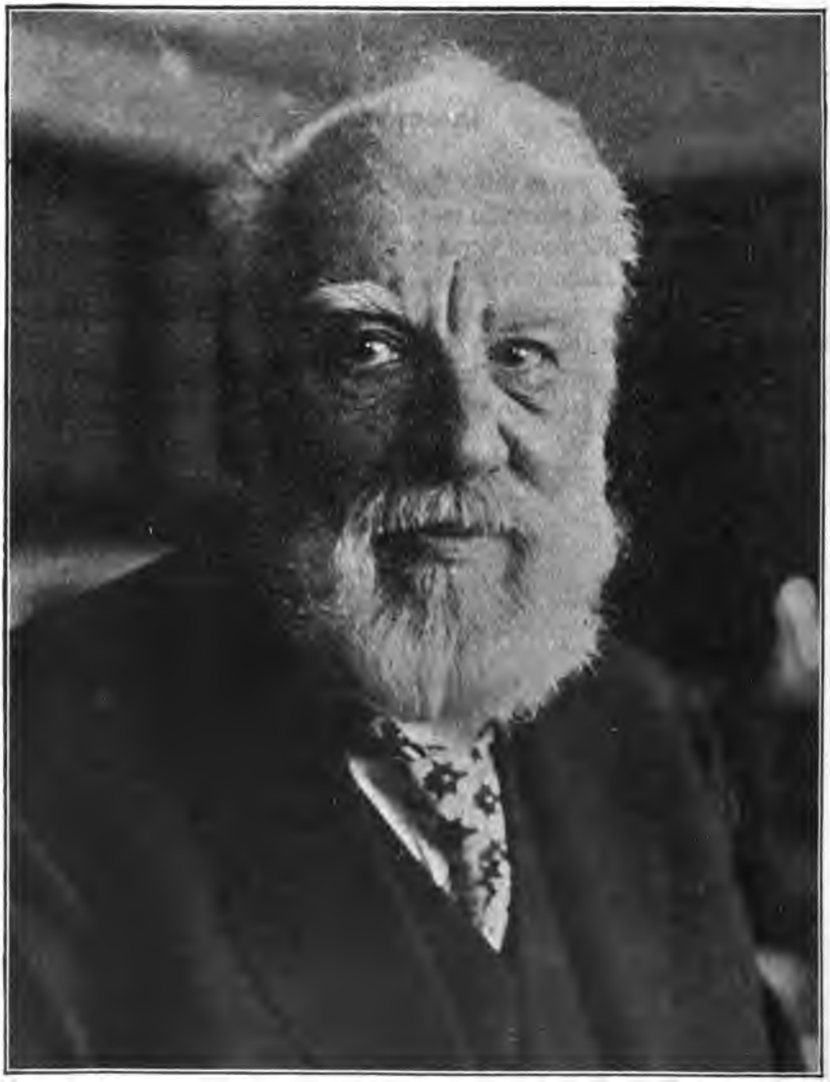
Wave Lengths in Meters.	Wave Lengths in Feet.	Frequency in Cycles per second.
200	656	1,500,000
300	988	1,000,000
450	1,476	666,666
600	1,969	500,000
1,000	3,280	300,000
2,000	6,562	150,000
3,000	9,882	100,000
6,000	19,685	50,000
8,000	26,247	37,500
10,000	32,808	30,000

Variation in Strength of Radio Waves.—The strength of signals received varies with the seasons. This is believed to be due to the absorption of the waves by vegetation during the summer, because there is a marked decrease in intensity of the radio wave during these months. Trees have been used as antennae with considerable success, which seems to demonstrate that they will also absorb radio energy. Rainfall has very little, if any, effect on the signal intensity of radio waves. The rays of the sun, however, have an ionizing effect on the atmosphere, during the day. That is to say, there is a certain power, called **electrolytic** power, in these rays which tends to decompose or change substances into their elements. This decreases the efficiency with which messages can be sent. When the sun goes down, the ionizing effect stops, and messages are more easily sent out.

Just how far radio waves can travel is unknown. It may be that some of them go on into space until they reach distant planets. In fact, it is believed by a few that signals, of unusual wave lengths, received by some scientists experimenting with radio may have come to us from other planets.

Questions

1. How do radio waves differ from light waves?
2. In what respect are radio and light waves similar?
3. What is the difference in radio frequency and audio frequency?
4. Why do not radio waves produce visible light?
5. Why are radio signals received better at night than during the day and better in winter than in summer.
6. What is the highest number of required vibrations a diaphragm of a telephone receiver needs to make to reproduce all musical sound and speech.



Dr. Alexander Graham Bell, inventor of the telephone and the system of visible speech.

The Production of Electromagnetic Waves.—To transmit signals by radio it is necessary first to produce electromagnetic waves in varying groups and of varying strength, and then to intercept them with apparatus capable of changing them to sound waves, or correctly speaking

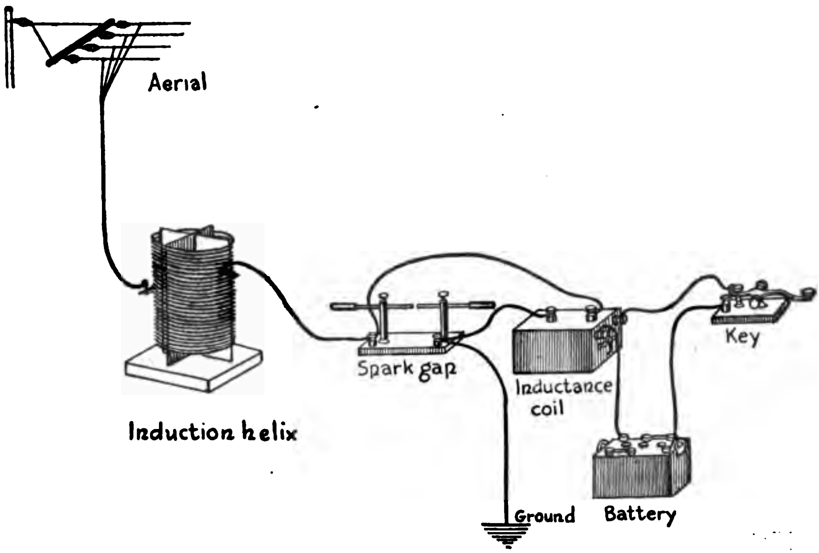


FIG. 10.—A simple sending set.

the radio waves cause the receiving instrument to reproduce the signals as sound waves.

To produce radio waves, it is necessary to have two surfaces separated by a distance of from ten to several hundred feet, and to produce between them an electrical pressure which changes its direction (first toward one surface; then toward the other) hundreds of thousands of times a second. It is a common practice to use the ground for one surface, and to provide another surface by erecting a structure composed of one or more wires insulated from the earth, and suspended

many feet above it. This surface is called an **aerial.** Between these, by means of suitable transmitting equipment, an electrical pressure of from one to many thousand volts is created, which starts waves radiating out in all directions.

These pressure waves, however, are only part of a radio wave.

The production of these waves may be compared to the action of hurling a large rock into a pool of water. The amperes (quantity) of current sent into the antenna correspond to the size of the rock, while the volts (force) of electrical pressure are equivalent to the force with which the rock is hurled. The larger the rock and the greater the force behind it, the larger the waves, and the farther they travel. The more amperes of current flowing in the antenna circuit and the greater the pressure (volts) between antenna and ground, the stronger the waves radiated and the farther they travel.

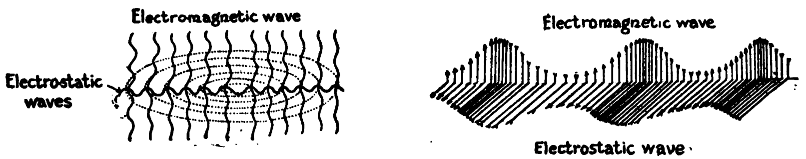


FIG. 11.—Radio waves are composed of electrostatic and electromagnetic waves which are traveling together at right angles to each other. The theory of the ether no longer is necessary for the propagation of electromagnetic waves. One can imagine waves being hurled through an absolute void just as readily.

Nature of Radio Waves.—The complete process of radiation of electromagnetic waves is very complex. In general, it can be said that the vertical wire and the earth can be considered as two sides of a condenser having a certain capacity. (A condenser is an instrument for storing electricity which will be explained a little later.) When one side of a spark gap has been attached to the earth and the aerial or vertical wire on the other side of the gap, **electrostatic lines of force** will be stored up in the space surrounding the aerial upon connecting the spark gap to a high-voltage current. When the charge becomes great enough, a discharge takes place across the spark gap, and a part of the electrostatic field is converted into current and the other part into wave motion. This wave motion consists of a **static field** which is constantly **changing.**

At right angles to this static field is a **magnetic field.** A radio wave is an electromagnetic wave composed of an **electrostatic field** and an **electromagnetic field** at **right angles** to each other, traveling together, out into space.

Radiation.—Electromagnetic waves are radiated when currents of high frequency are sent into the aerial. It is necessary to put into the antenna as much current (amperes) as possible at high pressure (voltage) and at high frequency. (10,000 cycles per second or more.)

High-frequency Currents.—High-frequency currents are currents alternating with great rapidity, going first in one direction on a wire, and then reversing the direction so as to go in the opposite direction. The current entering the aerial varies from positive to negative, and from negative to positive many times per second; it changes its direction of travel in the wire from several thousand to several million times a second.

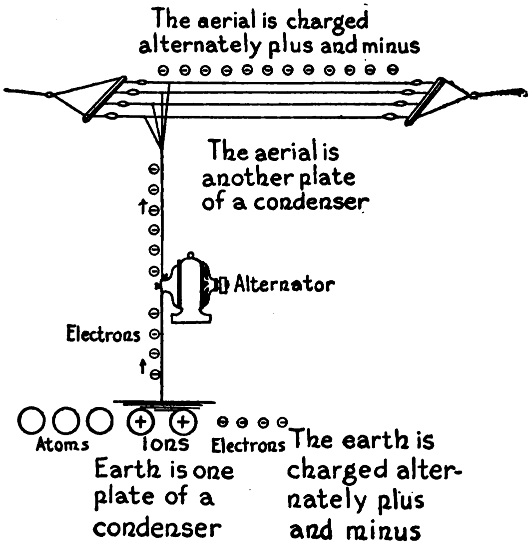


FIG. 12.—A diagram to show how an aerial is charged. Aerials have been buried in the earth and given excellent results.

Storing of Electricity.—When the generator operates it takes electrons from the wire attached to one side of the generator, and transfers

them to the wire attached to the other side. Every time the current changes, electrons are taken from the wire to which the electrons were sent. Thus the wires become alternately charged positively and negatively. It is necessary to have conductors or condensers capable of storing these electrons or electricity, on each side of the generator. Conductors so arranged as to store electricity are said to have **capacity.** The **larger** the **conductor** or **plate** in the **condenser,** the **larger** the **capacity.**

In sending-apparatus, the antenna may be called one plate of a condenser, and the earth another plate because charges are stored in each.

The Condenser.—The condenser can be said to be a true storage house for electricity and electrical energy. In other words, it is a reservoir in which electrical charges can be stored. The purpose of a condenser in wireless is to **store up electricity** and **electrical energy,** and it is used to produce an alternating electromotive force (voltage) due to its charge and discharge through a spark gap or other circuit.

Apparatus Required for Producing Radio-waves.—The apparatus used for transmitting radio waves consists of three essential parts: a **radio-frequency generator,** which will produce uninterrupted constant-amplitude alternating currents of exceedingly high frequency; a **modulator,** which will control the **amplitude** or **height of wave** of this alternating current, and **vary** the **amplitude** according to the amplitude of the sound vibrations to be transmitted; and the **radiator** or **antenna system,** which aids in converting the sound-modulated, radio-frequency currents impressed upon it into corresponding electromagnetic waves and radiates them into space.

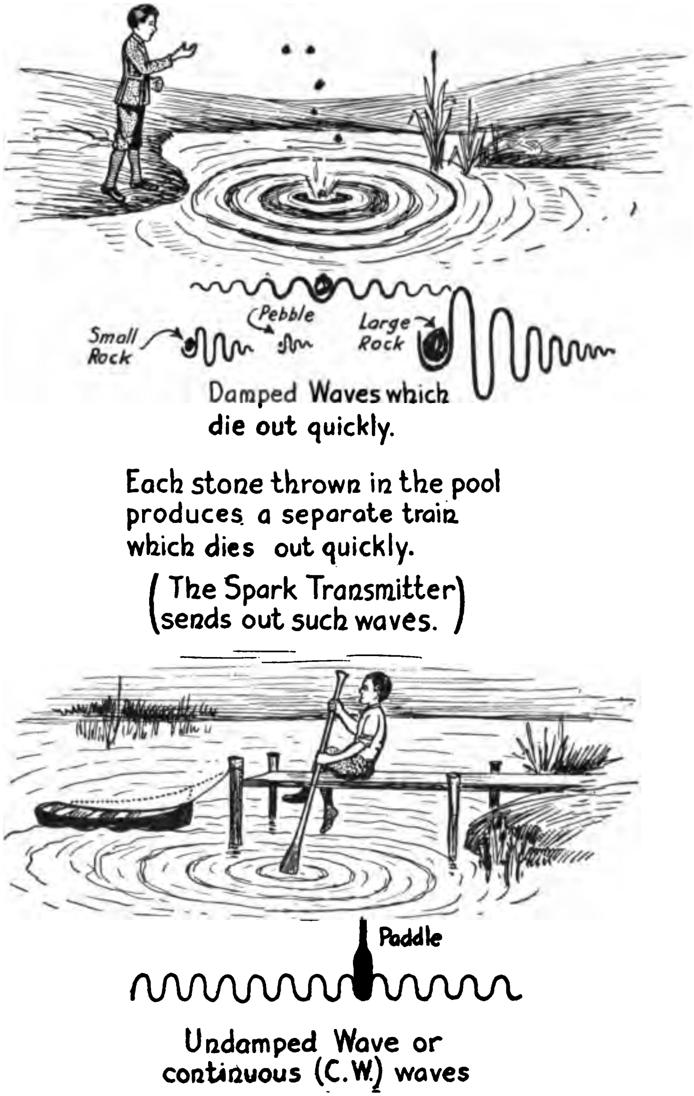


FIG. 13.—There are two kinds of waves used in wireless, the damped and undamped or continuous waves. The damped wave cannot be used for transmitting speech or music and the sound would be badly interrupted and unrecognizable, but the continuous wave can be modified or varied so as to correspond with the variations in the speech or music.

UNITED STATES GOVERNMENT WIRELESS REGULATIONS GOVERNING THE WIRELESS AMATEUR.

The Radio Regulations are easily understood and complied with. The regulations governing the amateur are as follows:

A receiving station alone requires no license, no matter how large or small it may be or the location thereof.

A transmitting station requires a license, which may be obtained, free of charge, from the Radio Inspector in charge of the district, and located at the Custom House in the following cities.

Boston, Mass.	Savannah, Ga.	Seattle, Wash.
New York, N. Y.	New Orleans, La.	Cleveland, Ohio
Baltimore, Md.	San Francisco, Cal.	Chicago, Ill.

Address: Radio Inspector, care Custom House, in the city in above list which is nearest you.

Power used for transmitting must not exceed 1 kilowatt and when a station is within five miles of a Government Wireless Station the power is limited to ½ kilowatt.

The transmitting wave length of the station must not exceed 200 meters. A copy of the "Radio Communication Laws" of the United States may be had from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 15c.

The Telephone Transmitter.—The telephone transmitter consists of a thin metallic disc or diaphragm usually made of aluminum. The sound waves from the speaker or instrument strike this diaphragm inside the hard rubber or metal mouthpiece, and cause it to vibrate, varying according to what is said, or what kind of sound waves strike it. This disc or diaphragm is attached to a plate on one side of a small chamber, which is filled with carbon grains or particles. The plate on the other side of the carbon grains is attached to the wire running to the other instruments. The plate next to the diaphragm is also attached to a wire coming from a battery or generator of electricity. The electricity flows to the plate, through the carbon particles, and out on the other wire. Whenever the diaphragm is made to vibrate back and forth, it causes the carbon grains in the chamber to be pressed harder together or released. Carbon grains loosely packed together form a poor conductor of electricity, but when the particles are pressed close together, more electricity passes through them than when they are released. The varying pressure of the wave striking the diaphragm causes a varying strength of current to pass through the carbon, and out

on to the wire leading to the other instruments. These currents vary according to the variation in the sound waves, and, if allowed to pass

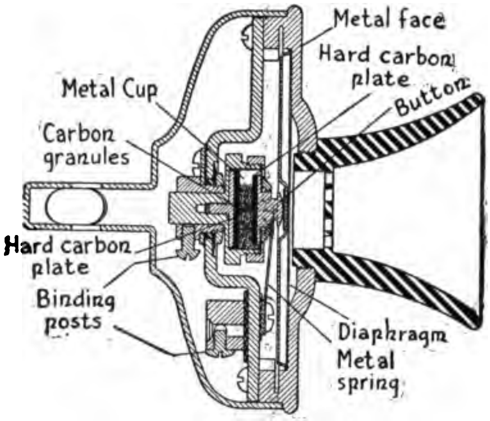
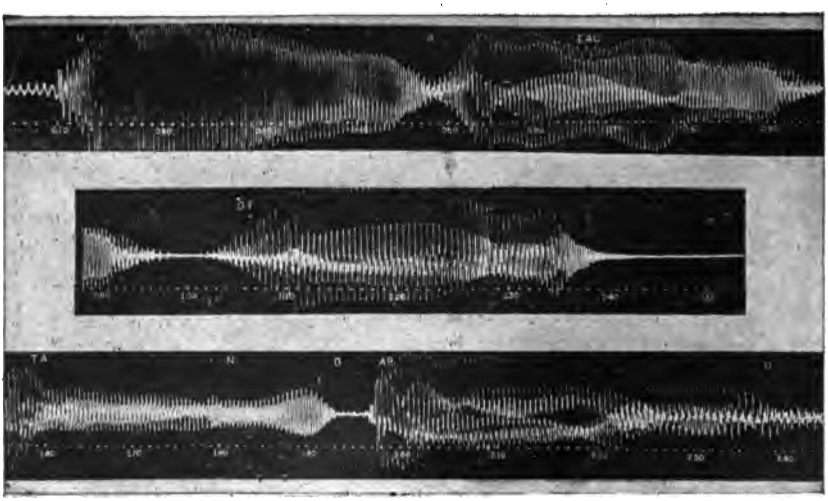


FIG. 14.—A diagram of telephone transmitters.



Dr. C. D. Miller, Case School of Applied Science

FIG. 15.—A photograph of the sound made by the human voice.* This picture is called an oscillogram.

over a telephone wire, will cause the disc in a receiver in another place to vibrate, and reproduce the sound of the human voice speaking into the mouthpiece.

How the Current of Electricity in the Transmitter Varies.—A battery or electrical generator is required to feed the transmitter. The telephone transmitter, then, is a kind of valve or throttle such as we might find in an automobile engine or locomotive. It permits certain currents to go through it, just as the valve of an engine can be opened partly, or entirely, permitting various amounts of steam or gas to enter the engine. In other words, the transmitter controls the amount of current, so that big or little spurts of electrical current will pass through the carbon particles, according to the kind of sound

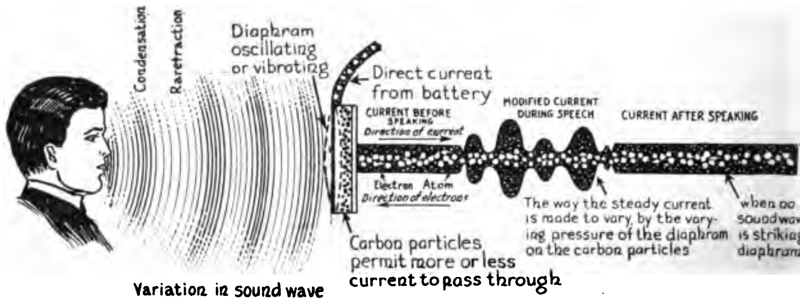


Fig. 16.—A diagram to illustrate the variations in the current which passes through a transmitter caused by sound.

waves that hit the diaphragm. These spurts or variations of current will resemble the variations in the sound wave that strike the diaphragm. It must be remembered that the transmitter has a continuous flow of current passing through the carbon particles all the time, and that this steady flow is varied according to the vibrations of the diaphragm. In other words, the transmitter molds or modulates the continuous current of electricity into variations or ripples, which vary like the sound wave that hits the diaphragm.

Speed of Sound and Electricity Compared.—It is not the sound that travels or is transmitted by radio. It is the electric wave which travels, at the rate of 186,000 miles per second, or nearly eight times around the earth in one second.

Sound travels only about 1100 feet per second, its speed depending upon the condition of the atmosphere or medium in which it is traveling.

If sound itself traveled, it would be a long time after a person spoke before the other party heard, especially if they were trying to talk across the continent.

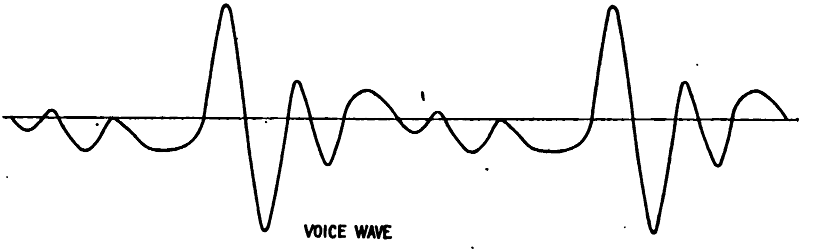


FIG. 17.—A diagram to show the current variations caused by a sound wave.

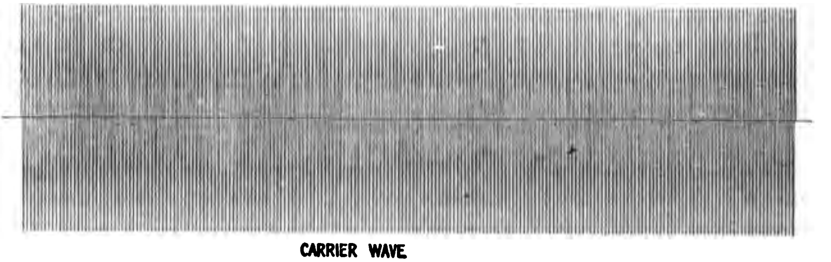


FIG. 18.—A diagram of a rapid oscillating current.

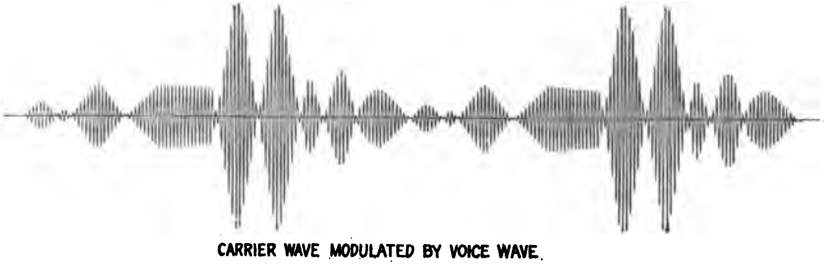


FIG. 19.—A diagram showing how the variations of a current caused by a voice are impressed on the carrier wave to modulate it.

Modulation.—In a wireless telephone, the sound waves strike the metal disc or diaphragm in the transmitter mouthpiece, and cause varying currents of electricity to pass through the carbon particles out on the wire connected to the container of the carbon particles. These varying currents are carried by a wire to one side of a **step-up transformer** (an instrument for increasing the voltage which will be explained a little later. See Fig. 20). By means of vacuum bulbs, also explained later, the current is increased and the variations magnified. A vacuum bulb also modulates a high-frequency current which is being sent to the aerial to correspond to the variations in the current produced by the voice. (See Fig. 20.) Before the current reaches the aerial, each variation produced by the voice is impressed upon a high-frequency current, of thousands of alternations per second, which goes to the aerial. In other words each one of these variations is composed of or broken up into thousands of rapid waves of high frequency by an oscillating vacuum bulb. These transmitting bulbs or tubes are very large, and are used to change direct current of from 350 to 2000 volts into alternating current with a frequency of from 50,000 to 2,000,000 cycles per second.

To generate a continuous wave (C.W.) and a modulated continuous wave, (M.C.W.) vacuum tubes of large sizes are used. By means of these tubes, we produce vibrations of current in a circuit in which are a coil composed of the single layer of wire, and the "condenser." The coil of wire provides "inductance," and the condenser provides "capacity," these two factors being necessary to an oscillation circuit.

The energy in the sound of a voice is very small; yet this small energy must mold, or modulate, or vary the amount of the current, and this modulated current controls a vastly greater energy produced by some kind of generator, which produces pulsations of current strong enough to send off powerful electromagnetic waves. Thus the small energy produced by the voice may control energy whose ratio to it may be as millions to one, just as a small boy may pull the throttle on a big locomotive and turn on power that will start a long train.

Electromagnetic waves properly modulated by sound waves give excellent results, even with the most difficult music. If the waves sent

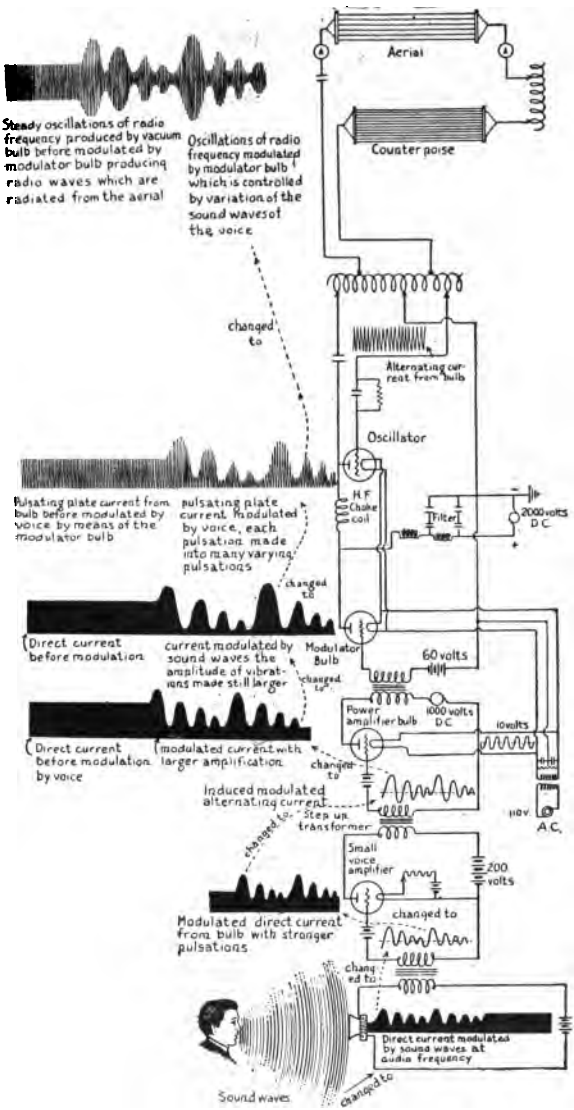


FIG. 20.—A diagram of a broadcasting station showing how voice and music is broadcasted. The diagram also shows how sound waves are changed to electrical vibrations and finally into radio waves.

out are under-modulated, the sound is faint; if over-modulated, the quality is damaged.

Transformers and their Use in Radio.—A transformer is made up essentially of two coils of wire, side by side, wound on a common iron core. When an alternating current is sent through one coil, called the primary, it magnetizes the iron core, causing surges of **magnetic flux,** or **lines of magnetic force,** first in one direction, then in another. The

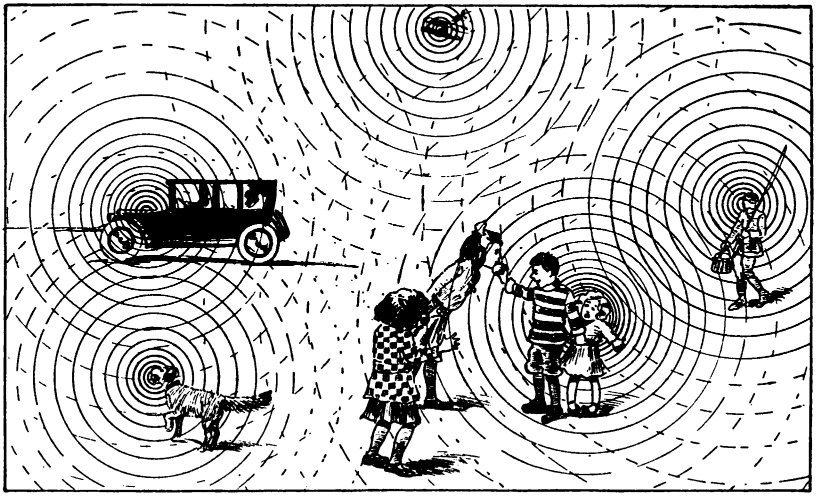


FIG. 21.—Sound waves travel in all directions from their sources.

magnetic flux passes through the second coil, called the secondary, as well as through the first coil. This induces an **alternating voltage** in the second coil. If the number of turns of wire on one of the coils is different from the number on the other, the voltage is different. There are two kinds of transformers, "**step up**" and "**step down.**" When a higher voltage is necessary than the alternating current generated, the voltage is "stepped up." That is, the current is sent through the coil having the smaller number of turns of wire and an alternating current of higher voltage is generated in the coil having the larger number of turns. For example:

If an alternating current is sent through one coil of a transformer

which has **ten times** as many **turns** as there are turns on the other **coil,** the induced voltage will be **stepped down** to **one-tenth** of the original **voltage.** If the **alternating current goes through** the **coil with** the **smaller number** of **turns** the **voltage** or electro-magnetic force E.M.F.

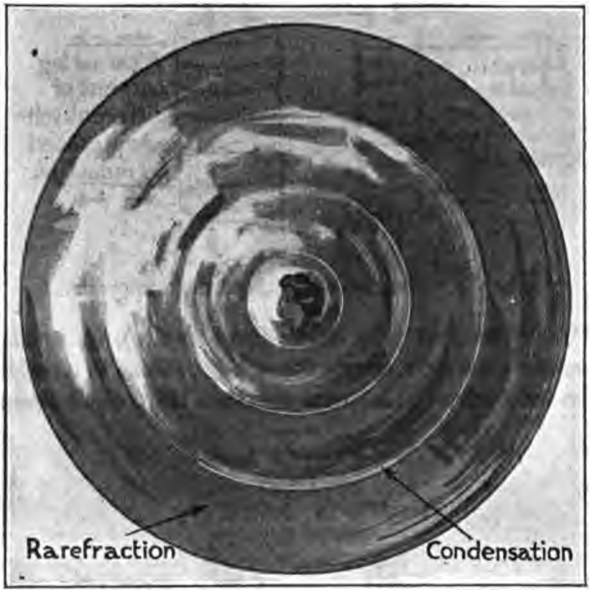


FIG. 22.—When any sound is made, sound waves are broadcasted in every direction in constantly expanding spheres until the waves becomes so weak they are no longer capable of producing sounds.

induced in the coil with the **larger number of turns** will have a **voltage ten times** as great.

Commercial transformers are built in two general types; the **core type,** in which the coils are wound around two sides of a rectangular iron core; and the **shell type,** in which the iron core is built around the coils. Transformers usually have the coils immersed in oil, and the whole thing surrounded with an iron case. Those seen on telegraph poles for use in lighting houses are of this type.

The transformer used for the wireless **steps the voltage up,** because

the pulsating current caused by the sound waves vibrating the diaphragm in the mouthpiece of the transmitter acts like an alternating current in the transformer. **The transformer has changed the direct**

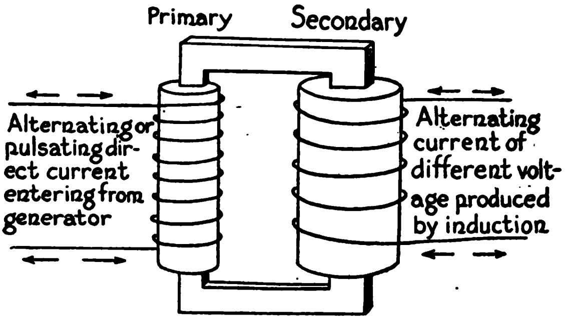


FIG. 23.—Diagram of a step-down transformer.

current to an alternating with more force (volts), in much the same way as the nozzle on a hose causes the water to issue in a smaller stream, but with greater force. This current differs from the stream of water,

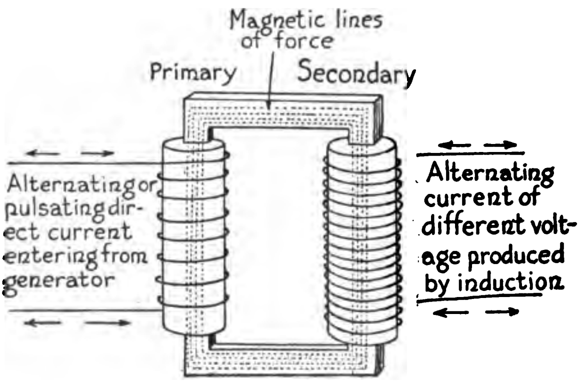


FIG. 24.—A diagram of a step-up transformer.

however, because an alternating current changes its direction many times per second. Alternating current produced by the generator, as well as by the variations in the voice, after being "stepped up" by transformers, runs into the antenna, causing lines of magnetic force

and electro static waves which produce radio waves. These waves radiate out in all directions.

Aerial at Sending Station.—The **aerial** is used as an instrument from which radio waves can be **radiated** or **flung** off into space. The

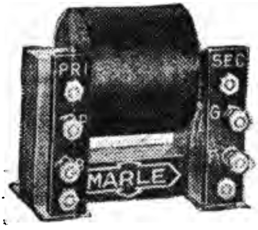


Fig. 25.—A radio-frequency transformer.

aerial wires are called an **antenna,** after the antennae or sensitive feelers of the butterfly. The higher the antenna the greater the range of the station. The **range** of any radio station depends on the **height and size of the aerial** and the **power available.**

Questions

1. Why do the ignition systems of automobiles and motor boats radiate (short) radio waves?

2. Why must an aerial be grounded?

3. What is the difference between continuous waves (C. W.) continuous modulated waves (C. W. M.) and damped waves (D. W.)?

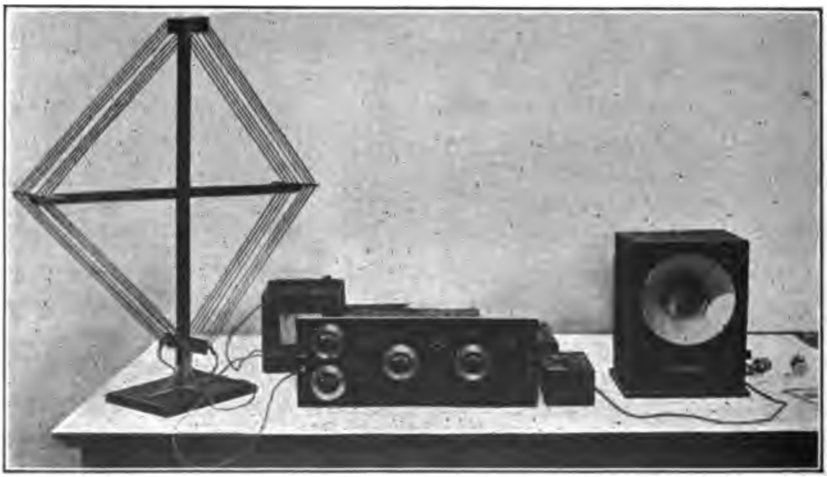
4. Why are C. W. waves used for broadcasting musical and vocal productions?

5. What would happen if D. W. were used?

6. Why is it necessary to modulate the high-frequency current sent to the aerial?

7. Why is it necessary to break up the modulated current from a transmitter into thousands of radio waves of varying amplitudes?

8. Why is it necessary to use step-up transformers for transmission of music and speech?



Complete super-regenerative receiving equipment.

How Sound is Carried.—It must be remembered again that sound does not travel from the aerial. The sound causes **vibrations** or **oscillations** of current in the antenna. These currents cause electromagnetic waves to go out into space. Another aerial is affected by these waves, making electrical currents oscillate in the receiving wire. These oscillating currents are like those oscillating in the sending apparatus. It is the variations in these oscillating currents that causes the diaphragm of the receiver to vibrate like the diaphragm of the transmitter, and produce sound waves like those produced by the voice or instrument which originally produced the sound that caused the transmitting diaphragm to vibrate.

Receiving Equipment.—For receiving, there are five **essential parts,** (1) an **antenna** or **aerial,** to intercept the electromagnetic waves; (2) **coils** (inductance); (3) **condensers** (capacity), **for tuning;** (4) a "**detector**"; and (5) **telephone receivers,** to make sound waves corresponding to the variations in the current coming from the detector. The detector or rectifier allows current to pass through it more easily in one direction than in the other, and changes the high-frequency current of many thousand vibrations or oscillations per second to impulses traveling in one direction in the circuit. The condenser and telephone receivers unite the many thousands of impulses in each variation of the high-frequency current into single impulses that can be heard by the human ear.

Receiving Conditions.—Messages can be received over land or water, over mountains or valleys. There is no character of topography which will forbid the use of radio-phone receiving sets, although, of course, the distance from which messages can be received by a given equipment is affected by the character of the country. They can be received through sun, rain, fog, and any atmospheric conditions, except for short periods when static electricity interferes. The duration of these interferences depend upon the particular locality and the season of the year. The static interference is a variable factor, but, in general, mes-

sages can be received for at least 99 per cent of the time. Reception is stronger in the winter-time than in the summer, and stronger at night than in the day, because the light-rays tend to neutralize the radio waves.

Interference.—Interference may be divided into three classes or types

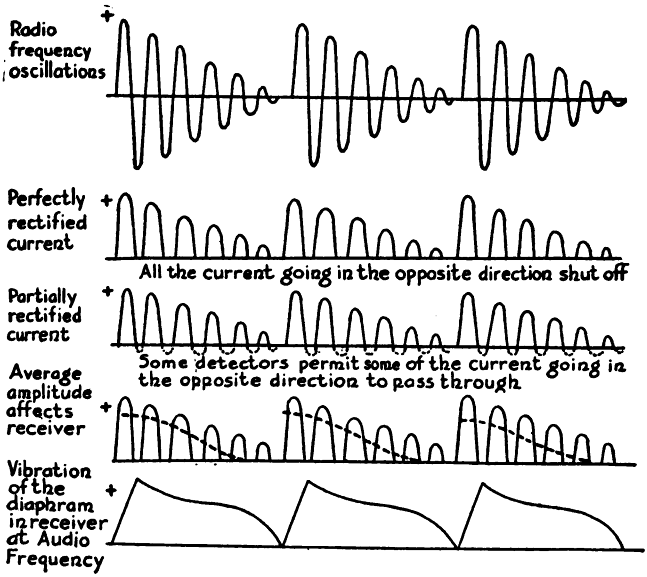


FIG. 26.—A diagram to illustrate the action of the detector, condenser and telephone receiver on damped radio waves. The same action takes place with modulated continuous undamped waves used for sending music, speech, and other sounds.

The first class of interference, mentioned above, is usually due to atmospheric conditions, caused by static electricity in the clouds, or moisture in the atmosphere, especially in the summer, when the particles of moisture, moved about by currents of air, pick up the free charges of electricity which are always present. Sometimes a cloud may gather enough charges to produce a flash of lightning. If a cloud or a collection of charged moisture particles passes near an antenna, the charges in the cloud will attract opposite charges in the ground. These

charges rise by means of the antenna and wires, causing a motion of electrons or current to flow. This flow will be indicated in the tele-

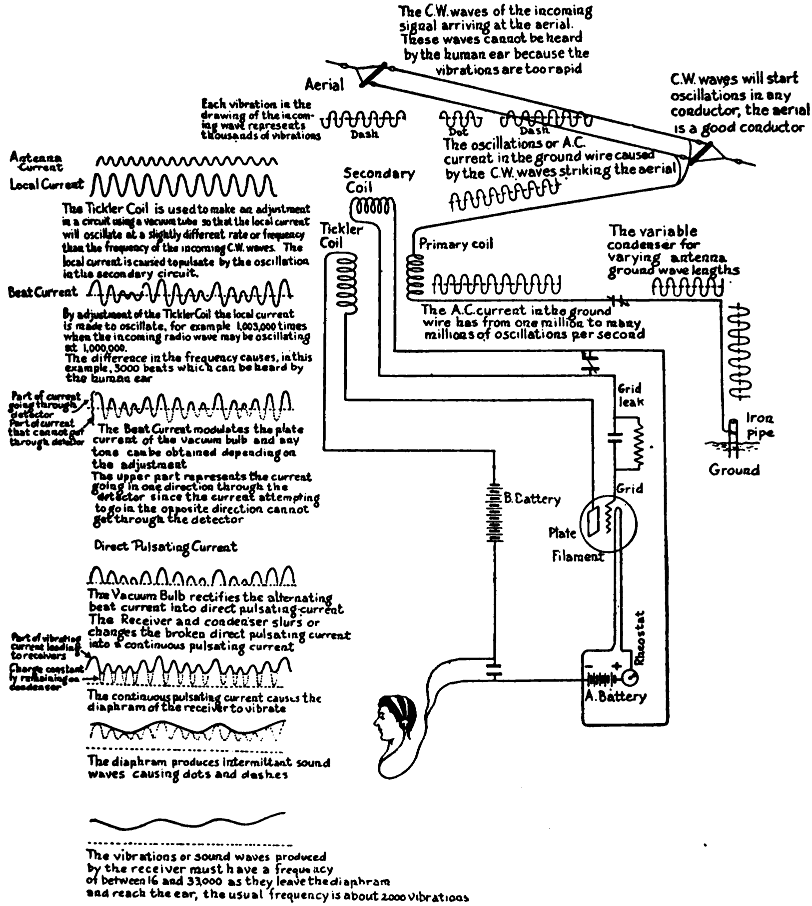


FIG. 27.—A diagram to show how continuous radio waves are made to produce buzzing signals in the receiver.

phone receiver by a cranking or crashing sound. This type of interference can be reduced by a **counterpoise** mentioned later, but in general it must be endured.

The second class of interference is produced by a faulty receiving station, or a faulty transmitting station, which sends out a number of varying wave lengths. The only remedy for this defect is "to loose" the coupling between the two coils of the high-frequency transformer so that one definite wave range may be obtained.

The third class of interference is that resulting from high-powered sparks, power stations, electric railways, trolley cars, and other kinds of electrical machinery. This type of interference is usually overcome by use of an **absorption circuit** * which is tuned until the interference is blotted out.

Aerial at Receiving Station.—The antenna absorbs energy in the form of oscillating currents from the electromagnetic waves which

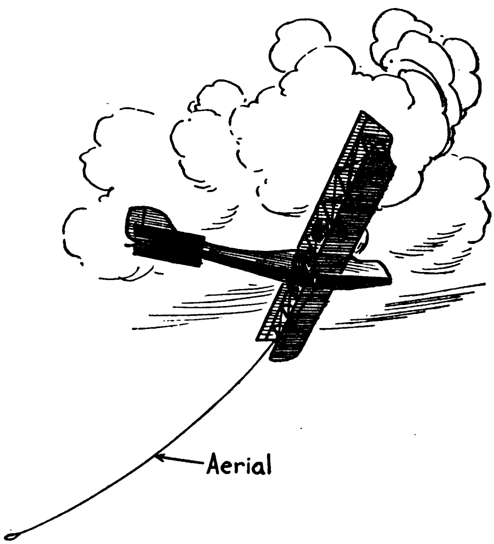


Fig. 28.

strike it. The higher the antenna, the greater will be the voltage induced. For ordinary receiving sets, a single-wire aerial of from 50 to 150 feet is used. This should be properly insulated at each end by the use of aerial insulators. The lead-in wire should be tapped

* A full description of the Absorption circuit can be found in *Radio Receiving*, published by D. Van Nostrand.

from the end of the aerial. It should be soldered to the aerial wire or well secured. If tapped at the middle, the effective length of the aerial will only be the greatest distance from the tap to the insulator, which results in a loss of a large percentage of aerial length. It is not advisable to use too long an aerial for the receiving of short wave lengths.

A *rough formula,* which is subject to considerable variation due to local conditions, for computing the correct length of aerial to obtain given results, is as follows:

The length of the aerial in feet, plus the length of the lead-in wire, multiplied by 1½ will give the approximate natural wave length of the aerial in meters. For example: Assume that the aerial is 135 feet long and the lead-in is 15 feet; this, multiplied by 1½, equals 225, which will be the approximate natural wave length of the aerial in meters. It should be borne in mind that the natural wave length of the aerial should be, in all cases, approximately 25 per cent below the minimum wave length of the signals which are to be received.

Amateurs having small assembled crystal receiving sets should bear in mind that the antenna should conform as closely as possible with the formula given, if they desire to receive music and voice from broadcasting stations.

It is better to increase to a given wave length than to decrease. Most amateurs having sending stations use wave lengths of under 200 meters; hence, an aerial 150 feet in length including the lead-in would have to be decreased by the use of a variable condenser in the aerial or ground circuit to receive most amateur signals. An antenna, however, of 150 feet in length including the lead-in would be perfectly satisfactory for the reception of voice and music from broadcasting stations which usually transmit on a wave length of 300 to 360 meters.

With the more elaborate sets it will be found possible effectively to increase a comparatively short antenna to the necessary 360 meters to receive broadcasting, which would not be possible on the small crystal sets unless they were located very close to the broadcasting station.

Most wireless receiving sets, no matter what their maximum normal wave length is, can by the use of loading, duo-lateral or **honeycomb coils** have their wave length increased to any desired point to receive signals from stations transmitting on a greater wave length. Wave lengths should not be confused with distance. Wave length has nothing to do with the distance that a set will receive. Most small assembled crystal detector sets may, by the addition of a coil of the necessary

inductance, be made so that they will receive signals from stations operating on a longer wave length than could normally be received. They would not, however, receive these signals from a greater distance than they would receive short wave-length signals, provided, of course, that both stations operate on the same power.

Insulation is of utmost importance. Leakage of current through faulty insulation means a large loss of power. If this leakage is large the aerial circuit will not operate and it will be impossible for the station to receive messages.

Height of Aerial.—The **height of the aerial** is important. It should be located either on the roof or as high as possible from the ground. This is particularly important where there are high buildings or high trees in close proximity. It should in all cases be higher than the surrounding buildings and trees to secure the best results.

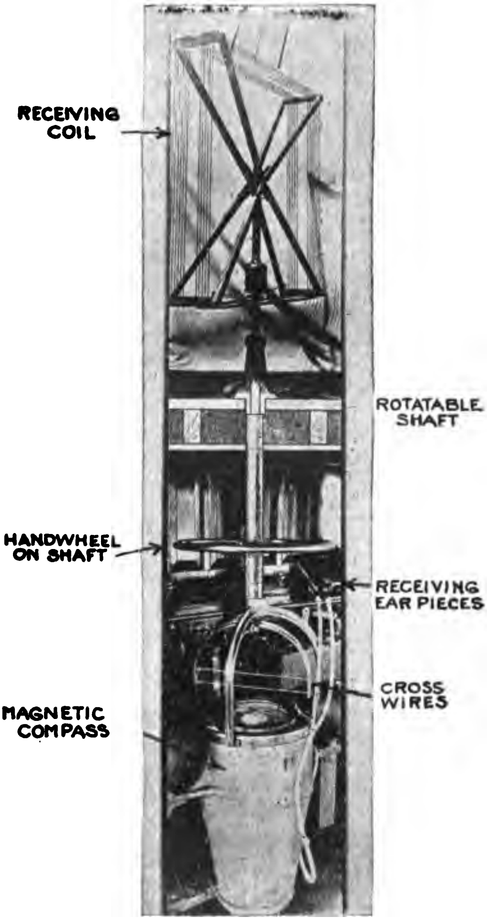
Where the aerial is erected over a tin or metal roof, it is desirable to have it at least 8 or 10 feet above the roof. Great care must always be taken lest trees, steel buildings or metal roofs interfere with the electromagnetic waves.

Position to Get Best Results.—According to theory the aerial that would have the best results would be one that would be placed in such a position as to be at right angles to the magnetic field and parallel to the static field. But the radio waves are distorted as they pass over the dry earth. The bottom of the wave travels more slowly than the top of the wave. Hence an aerial that will have a part horizontal and a part vertical will receive the greatest induction (give the best results).

Ground Connection.—Every outfit in addition to having an antenna connection must have a ground connection. This connection can be made to a water pipe or radiator by a suitable ground clamp. Care should be taken to scrape off any paint or corrosion outside of the pipe before attaching the ground clamp. If a connection is made to a gas pipe it should be made between the place where the pipe enters the ground and the gas meter.

Counterpoise.—Sometimes where ground connections are impossible, a wire or set of wires is arranged like an aerial, usually under the aerial. This arrangement is called a counterpoise. No ground connection is required, as the counterpoise (instead of the earth) acts as the other plate to the condenser. The counterpoise radiates electro-

magnetic waves, but is so arranged as to have very poor radiation as compared with the aerial.



Courtesy Popular Radio Magazine

FIG. 29.—A loop aerial used as a radio compass in a lighthouse.

The best place for a counterpoise is about three feet from the earth, but this is not always possible because it may be damaged. If placed six or seven feet high it is out of the way of passing people.

The best place for the counterpoise is directly below the aerial and in the same direction as the aerial; however, it will work if run in the opposite direction. The counterpoise should be well insulated, and its lead-in wire should be kept at a distance from the aerial lead-in wire, to prevent losses by induction between the two wires.

Sometimes where the ground is very dry the counterpoise is placed on the ground in the form of a network of wires, and at still other times it is buried in the earth deep enough to keep the wires or copper plates in moist earth.

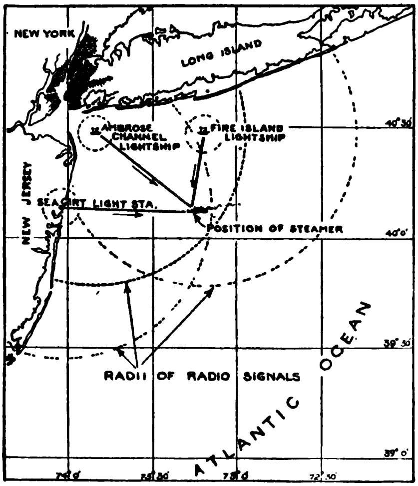


FIG. 30.—How a radio compass aids in determining a ship's position.

The metallic surface should always equal in extent the metallic surface of the aerial, and in most stations it is larger. The spread, or distance between the outside wires of the counterpoise must be greater than the spread of the aerial to prevent a change in the capacity when the aerial swings in the wind.

In aeroplanes and air-ships the framework is used for a counterpoise.

Loop Aerials or Radio Compass.—In place of the elevated aerial, **coil** or **loop** antennas (coils of wire of moderate dimensions) are often used. These aerials have been used inside of buildings, and even inside

phonograph cabinets, so as to do away with the outside aerials. The loop aerial does not work very satisfactorily on the ordinary crystal set, but is popular because it is so compact.

Loop aerials receive best when turned in the direction from which the radio wave is coming; that is, when the direction of the wires or windings is in the direction of the sending station.* Radio sets fitted out with loop aerials may be used as **radio compasses.** Ships at sea may be located by the use of such aerials. A ship wishing to know its exact bearing may call two radio compass stations in different directions on shore. Each station will tell the ship at what angle its message was received. With the use of the angles and the known distance between the stations the ship will be able to find its location.

Freak Transmission.—Layers of reflecting material, which cause radio waves to be carried great distances, are often formed in the air. This is called **freak transmission.** Sometimes such conditions make it possible to hear from very distant stations. Often the signals received from beyond the normal range will fade out, only to return again with great intensity in a few moments.

Inductance.—The strength of a current in the antenna circuit can be increased by inserting a few turns of wire wound on a tube of some insulating material. The coil acts like an electromagnet, except that it has no iron core. The coil is surrounded by a magnetic field. The **larger** the **number of turns,** the **larger and stronger this magnetic field.** The property of a coil or other portion of an electric circuit which enables it to **store energy in the magnetic field** is called **inductance.**

Inductance is measured in units called the henry, millihenry, microhenry. Capacity is measured in units called microfarad, millimicrofarad, and micromicrofarad. These units are named from Joseph Henry and Michael Faraday, two leaders in electrical discovery.

Condenser and Capacity.—A condenser is used to store electricity. In general the larger the condenser the more electricity can be stored,—the greater its capacity. A condenser is usually made of two or a number of sheets or plates of brass, aluminum, copper, or tinfoil, separated by some non-conductor of electricity, called a **dielectric.** This material may be a gas, such as air; a liquid, such as oil or water; or a

* When the sending station is "in the plane" of the wires of the loop.

solid, such as mica, glass, or paraffined paper. Alternate sheets or plates are connected to one wire in the circuit, and the remaining sheets

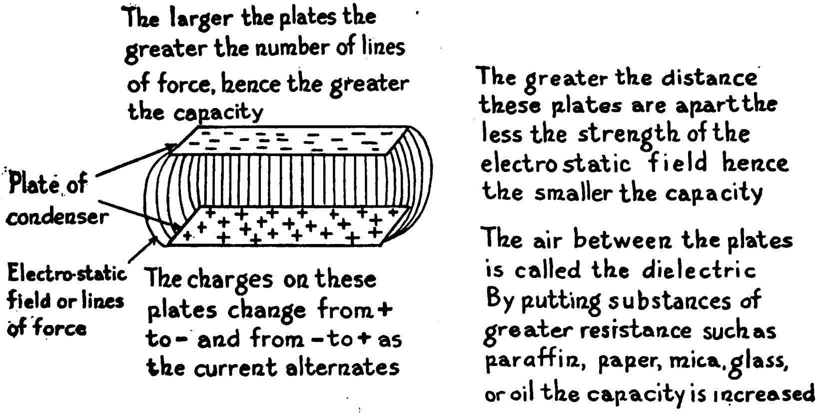


Fig. 31.

Fig. 32.—A variable condenser. Changing the position of one set of plates by rotating one set between the other set, the capacity of the condenser can be changed.

are connected to the other wire. The current enters the plates and builds up a static pressure, like that occurring in the antenna circuit, until the

pressure is great enough to overcome the onrush of electricity; then there is a rebound as the condenser is discharged, and the opposite set plates charged by the electrons. The number* of electrons required to produce a certain potential difference (voltage) is called the **capacity** of the condenser.

FIG. 33.—A panel-board type of variable condenser.

In a tuned circuit the action of a condenser can be compared to a billiard ball which hits the cushion with a certain momentum. The ball rebounds as soon as the cushion gives back to the ball the energy acquired in stopping it. The electrons lose their momentum in producing a strain in the dielectric which opposes their direction of motion, and tends to cause a motion in the opposite direction, just as the cushion on the billiard table causes the billiard ball to take another direction. The cushion of the billiard table serves the same function as the dielectric in the condenser. Another comparison of the action of a condenser can be seen in the hair spring of a watch which causes the balance wheel to oscillate back and forth in opposite directions, as the coil winds and unwinds.

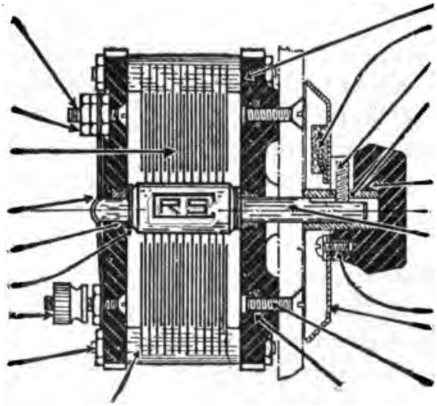


FIG. 34.—Parts of a variable condenser.

* Quantity of electrons or quantity of charge.

Why Tuning is Necessary.—The **inductance** in a circuit stores up **motional energy** (kinetic energy) in the form of a **magnetic field.** The **capacity** of a circuit stores up the **energy** (potential energy) in the form of an **electrical stress** in the dielectric between the condenser plates. Such a circuit will have a natural frequency of vibration, just like the pendulum of a clock. The electrical stress or capacity may be compared to the spring that moves the pendulum, while the weight (mass) of the pendulum may be compared to the inductance. It is known that when one tuning-fork is sounded, a near-by fork of the

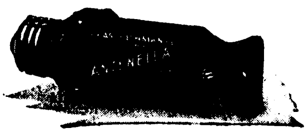


Fig. 35.—Antenella plug, one type of instrument used in an electric-lamp socket in order to permit electric-light wires to be used as an aerial.

same pitch will start vibrating in sympathy, due to the sound waves sent from the vibrating fork, while a fork not in tune (not of the same pitch) with the vibrating fork will not be influenced. Likewise, when the note A is struck on the piano, the sound waves vibrate 435 times per second, and either an A tuning fork, or a wire tuned to A, in the immediate vicinity, will vibrate 435 times per second also. This is called sympathetic vibration, and the two wires may be said to be in **resonance.**

Radio waves have characteristics similar to those of sound waves. The electromagnetic waves radiated by a radio transmitter always have a definite number of vibrations per second. The waves sent from one aerial will produce currents in another aerial which has a natural period of oscillation the same as that of the circuit which sent off the electromagnetic waves. In order to hear a station, therefore, the receiving equipment must be put in resonance with the waves radiated by the transmitter. This operation is known as tuning. The tuning of a circuit is effected by **varying** either the **inductance** or the **capacity,** or both the inductance and capacity **until the natural period** of the circuit is the **same** as that of the **incoming waves.**

Variometer.—When two connecting coils are placed one inside the other, so that one coil can be turned about or rotated half a revolution

FIG. 36.—A Variometer. When the inner coil which is connected with the outer coil so that the current passes through both coils in the same direction is rotated, the magnetic field of the inner will oppose that of the outer coil. At a position of just one-half a turn the opposition is the greatest and the inductance of the coil small. By rotating the inner coil to different positions the inductance can be varied.

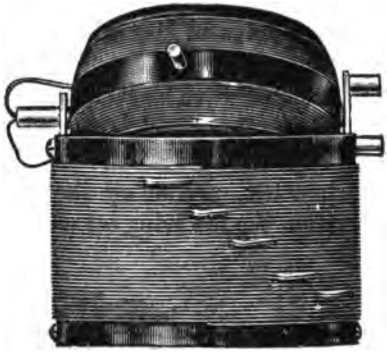


FIG. 37.—A Vario Coupler. When two coils one inside the other are not united they act as a primary and secondary coil and this type of instrument is called a vario coupler. The amount of inductance is varied by rotating the inner coil within the outer so that more or less lines of force pass through it.

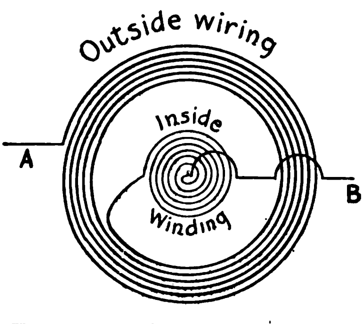


FIG. 38.—A diagram to show the windings of a vario-coupler.

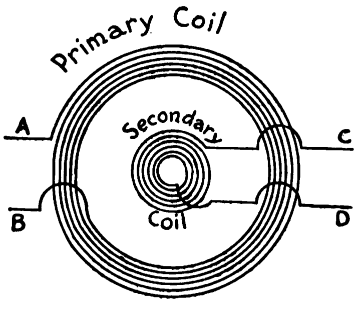


FIG. 39.—A diagram to show the windings of a variometer.

(180 degrees), the inductance can be made large or small, because the magnetic field of one coil can be made to combine with or to oppose the magnetic field of the other coil. When the inner coil is turned so that the two coils are in the same direction and the current circulates through the windings in the same direction, the magnetic fields combine and produce the greatest inductance. This position tunes the set to receive the longest wave lengths the set is capable of receiving.

If the inner coil is turned half way around, the current circulates through the coils in opposite directions and their magnetic fields oppose each other, producing the smallest amount of inductance. In this position the receiving set will receive shorter wave lengths.

FIG. 40.—Duo lateral, Honeycomb Coil.

Any amount of inductance can be secured and any wave length within the range of the set may be obtained by rotating the inner coil to any desired angle. An instrument with this arrangement of coils is called a **variometer.**

Vario-coupler.—In a vario-coupler the wire on the outside winding or primary coil has no connection with the wire on the inside winding or secondary coil. When a current of electricity is sent through the outer or primary coil, a voltage is induced in the inner or secondary coil and the coils are said to be **coupled or loose coupled.** The inner coil is usually placed in the end of the outer coil. If the inner coil is turned, the amount of voltage induced in the secondary coil varies. When the coils are turned so that their windings are at right angles to each other, the least amount of inductance is obtained.

Loose Coupler.—When two coils are wound on tubes and the secondary coil slides in and out of the primary coil, in this way increasing or decreasing the inductance the instrument is called a **loose coupler.**

Other Couplers.—Other devices called honeycomb coils, basker or spider web coils, can be used as couplers to vary the inductance of the circuit. They are generally hinged at one side and open and close like the leaves of a book. One of the advantages of these coils is that they have less capacity and so consume less energy from the circuit.

Close Coupling.—When the same tuning coil is used for both primary and secondary circuits and the inductance of each circuit is varied by means of sliders, the circuits are said to be **close-coupled.**

FIG. 41.—Loose Coupler.

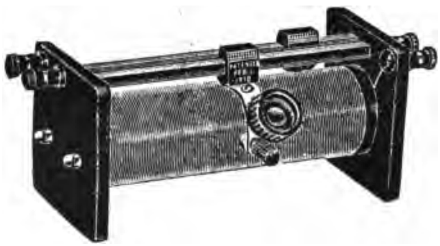


FIG. 42.—Close Coupling.

The Detector.—The electric current of radio frequency cannot readily be sent through a telephone receiver because of the thousands of turns of fine wire about the electromagnet which operates the diaphragm. The current would be "choked back." Another reason why a radio-frequency current, even if it were possible to send it through the receivers, cannot be used, is that there is no diaphragm made which will respond to the high frequency of radio. The average diaphragm responds only to a few thousand cycles per second. A third reason is that the average human ear will not respond to vibrations much over 10,000 cycles per second. The high-frequency current must, therefore be changed so as to pass through the receivers, and must be so modified as to affect the diaphragm. This is done by a "**detector,**" or **rectifier.**

Rectification.—All currents received by wireless must be rectified; that is, made into direct currents as far as possible. When either the negative or the positive pulse of an alternating current is practically

obliterated by an instrument called a detector, the detector is **said** to be a very good type and the current is said to be rectified.

The **greater** the **difference** in the **conductivity** of a crystal to **current in opposite directions,** the more **perfect** the **rectification** will be.

Types of Detectors.—There are two types of detectors in use to-day. One is known as the **crystal detector** and the other as the **audion detector,** or **vacuum tube detector.** It was found early in radio work that certain minerals possess the property of permitting current to pass freely in one direction, but not in the opposite direction, to any extent. Such

FIG. 43.—A Crystal receiving set.

FIG. 44.—An Audion set.

FIG. 45.—Combination of condenser tickler coil variometer.

A Combination of Tuning Instruments.

crystals are suitable for radio work. Galena, silicon and carborundum are the names of the crystals commonly used.

Crystal Detector.—The crystal detector consists of a mineral set in a suitable cup or clamping device. When a sharp steel or bronze wire is brought in contact with certain spots on the surface of the crystal, currents will pass through more easily in one direction than in the other direction. It is the **difference** between the amount of **plus** and **minus** currents which go through the crystal that determines the value of the crystal.

CRYSTALS.—Bornite Carborundum, Copper Pyrites, Galena, Graphite, Tellurium, Iron Pyrites, Nagyagite, Perikon, Silicon, Sylvanite, and Zincite are used for rectification and detection of small radio-frequency currents.

Courtesy of Radio News

FIG. 46.—Microscopic Picture of a Galena Crystal. The difference between the plus and minus currents which go through the crystal determines the value of the crystal.

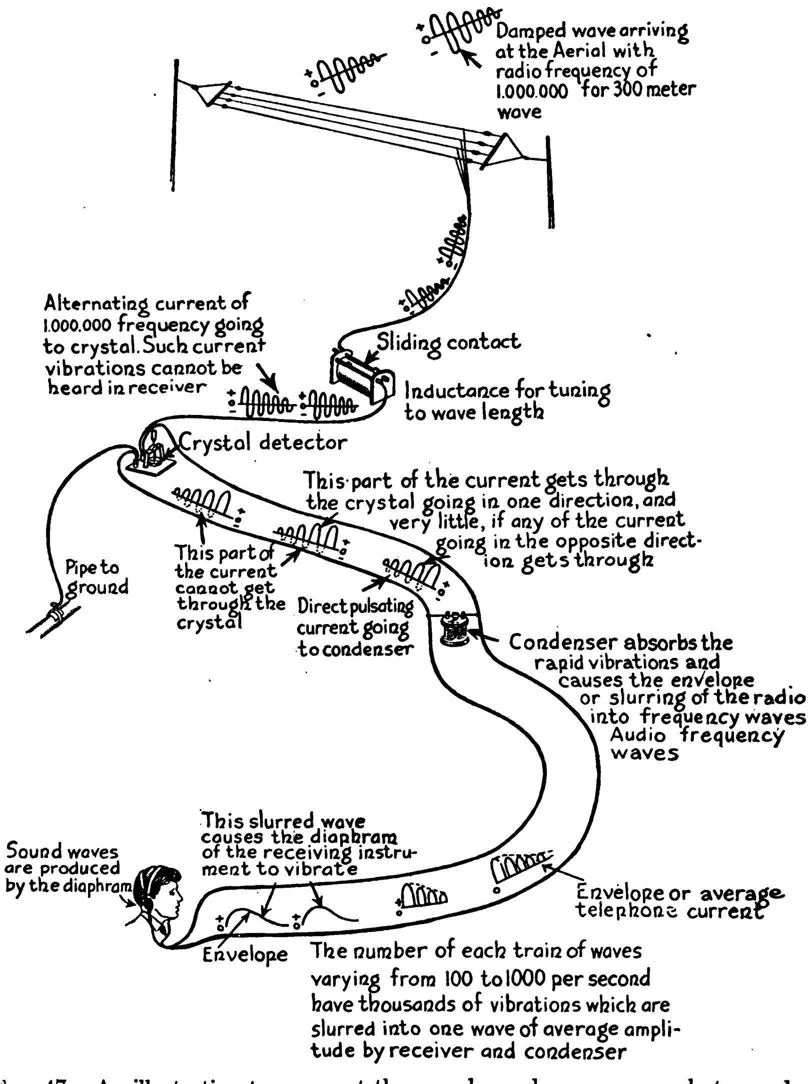


Fig. 47.—An illustration to represent the way damped waves are made to produce sound waves.

Crystal Sets.—Small assembled crystal receiving sets will not receive music and voice from broadcasting stations located over 25 miles away; in fact, under certain conditions, particularly where there are a large number of high steel buildings near by, small crystal receiving sets will not operate satisfactorily over 15 miles from broadcasting stations. In assembled crystal receiving sets the only parts required are: a pair of telephone head receivers, a suitable crystal, a condenser, tuning coil, the antenna and the ground connection. There are no bat-

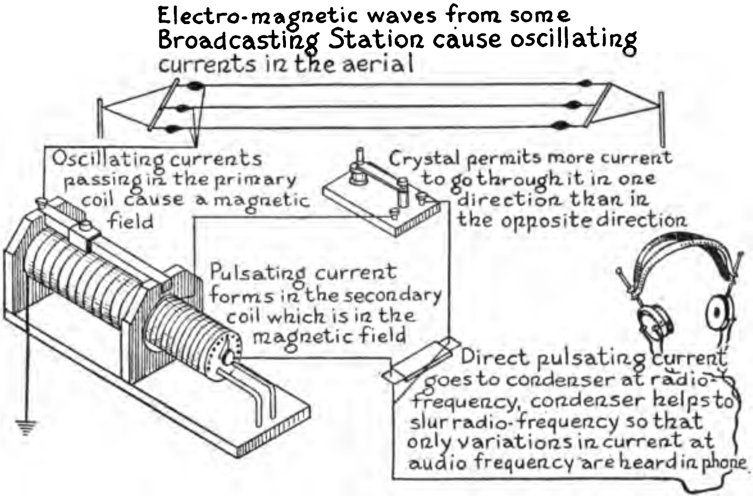


FIG. 48.—Crystal receiving set.

teries used and there is nothing to get out of order or be renewed, except the crystal, which costs very little.

The Vacuum Tube.—It has already been stated that the means whereby the voice can be used to control the great oscillations of electricity is usually the vacuum tube, the most interesting instrument which has been developed in radio work, and one of the most sensitive instruments known to science. The tubes are called by various names,—aeriotron, audion, electron relay, oscillion, pliotron, and radiotron.

Construction of Vacuum Tube.—A vacuum tube consists of a glass container shaped like an electric lamp, from which all air or other gas has been carefully evacuated. In this are enclosed three metallic

terminals or electrodes, an **incandescent filament,** a **grid of fine wire** surrounding the **filament,** and a **cylindrical metal plate** which surrounds both the filament and the grid.

Vacuum Tube Detectors.—A current of electricity flowing from a **high potential** to a **low potential** is in reality a stream of negative charges flowing from a negative to a positive potential. When we speak of a current of electricity flowing along a wire we are really speaking of the

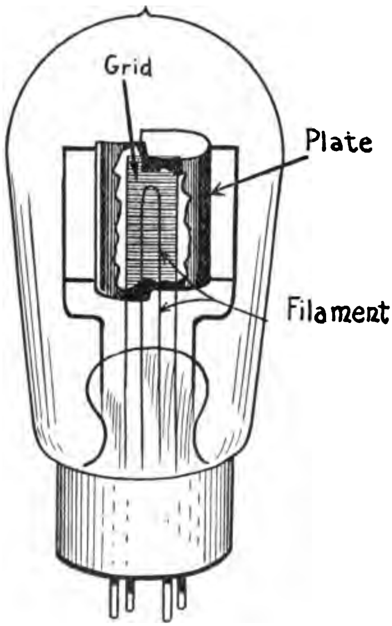


FIG. 49.—Parts of a vacuum tube.

passage of a **stream** of **electrons** flowing through the wire. In general, this statement holds true whether the material through which the electrons flow is a solid, a liquid, or a gas. This is also true of a pure vacuum. When a tungsten wire is sealed into a glass tube from which the air has been exhausted and this tungsten wire heated to incandescence by a current of electricity from a battery (in a circuit), a certain number of electrons make up the heating current, and the other elec-

trons "not used" for heating purposes vibrate with constantly increasing energy as the wire rises in temperature.

If the wire becomes hot enough, the vibration of these electrons will become violent enough so that many of the electrons will break through the surface tension of the metal, and escape. The space around the filament or wire inside the bulb will soon become filled with electrons.

The Action of the Filament.—The filament is a piece of high-resistance tungsten wire, which is heated by electric currents to brilliancy,

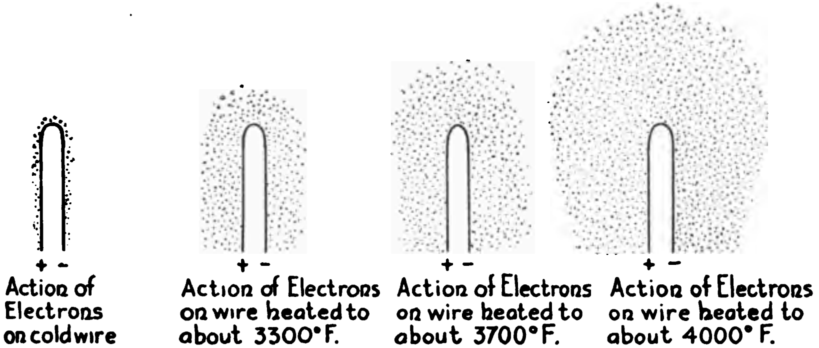


FIG. 50.—A diagram to illustrate the action of electrons about the wire filament, as the temperature of a filament in a vacuum bulb increases.

Every filament has a certain temperature above which no more electrons will be radiated or thrown off. Vacuum bulbs should be operated at the lowest possible temperature that will give good results.

as in an electric light. When this filament is heated, millions of electrons escape from it. Tungsten, the metal used for the filament, appears very hard and dense, but, in reality, it is spongy and porous, being made up of a very large number of atoms or molecules. As has been already said, each of these atoms consists of a positive nucleus, surrounded by electrons. The atoms, as well as the free electrons of a metal, are constantly in a state of violent motion in all directions. When a **metal is heated,** the **motion** of the **electrons increases.** When a metal is sufficiently heated, electrons will actually jump away from the atoms. The metal is then said to be **evaporating.** Evaporated tungsten fre-

quently causes the ordinary electric light bulb to become blackened on the inside.

Most of the vacuum bulbs use tungsten for the filaments, because of the low temperature at which the metal begins to evaporate, giving off a sufficient number of electrons at a temperature low enough to give the filament a long life. Sometimes the hot electrode is made of a thin narrow platinum ribbon, coated with oxides. This filament requires only about one-half as much power to evaporate the electrons as do filaments made of pure tungsten.

FIG. 51.—One type of vacuum bulb used for receiving.

The Electron Bridge.—When an additional wire or a plate is inserted in an electrical bulb, and the filament in the bulb heated to incandescence, a current will flow across the vacuum between the filament and the plate or wire. The electrons will pass only from the hot filament to the cooler plate or wire. This is due to the fact that the white-hot filament gives off millions of the infinitesimal electrically charged units called electrons, which travel to the plate or wire. These electrons form an electrical current which can flow in one direction only. This type of bulb with two electrodes, is used to change alternating currents to direct currents.

Why the Plate is Needed in a Vacuum Tube.—As soon as a great many electrons have accumulated in the space around the filament these electrons will prevent others from leaving the filament by repelling them, and a condition will result when no more electrons will be given out. If a metal plate is placed in the bulb and this plate made positive, by means of a battery which we will call a "B" battery, a current of electrons will be found to be flowing toward the plate when the filament is hot. This is because the electrons are attracted to the positive plate. A current or stream of electrons flows from the hot filament to the plate, then along the wire to the battery, through the battery back to the filament, and so on. In wireless, this circuit is called the **"B" circuit.**

If the connections of the battery are reversed so as to make the plate negative no current will flow, because the plate will repel the

electrons and tend to prevent them from coming out of the filament. This shows that only a current going in one direction will flow through the bulb or vacuum tube. In other words the plate must always be impressed with a plus or positive potential.

Now, if an alternating current is supplied in place of the battery the plate will become alternately plus and minus; but the current will flow only from the plate to the filament. Hence the bulb can be used

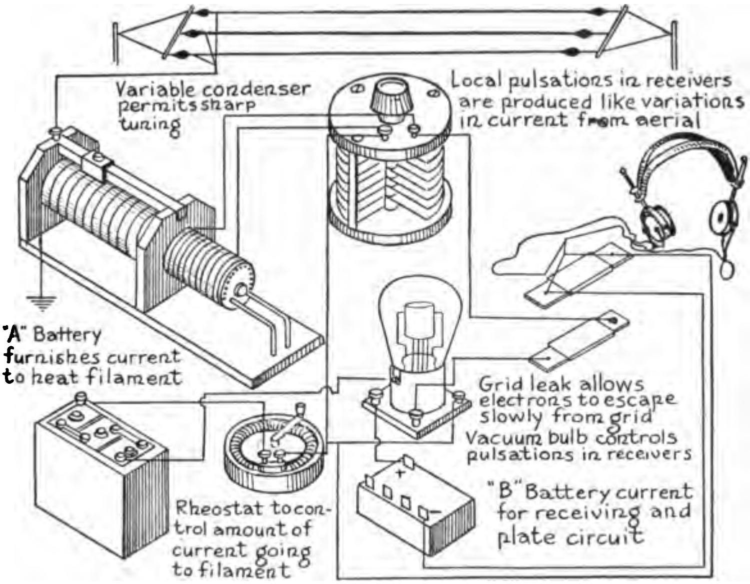


FIG. 52.—Vacuum bulb receiving set.

as a rectifier of alternating currents. Such an instrument as this is called a Fleming Valve.

The Plate and the Grid.—From the evaporating tungsten filament, the electrons go to the plate, and so return to the circuit. Electrons can travel only from the hot filament to the comparatively cold plate. They cannot reverse and go the other way. It is this property which is utilized when employing the vacuum tube as a detector for changing the radio waves of vibrating currents into direct-current impulses.

It is necessary to have some means of controlling the number of electrons which pass from the filament to the plate, and, for this purpose

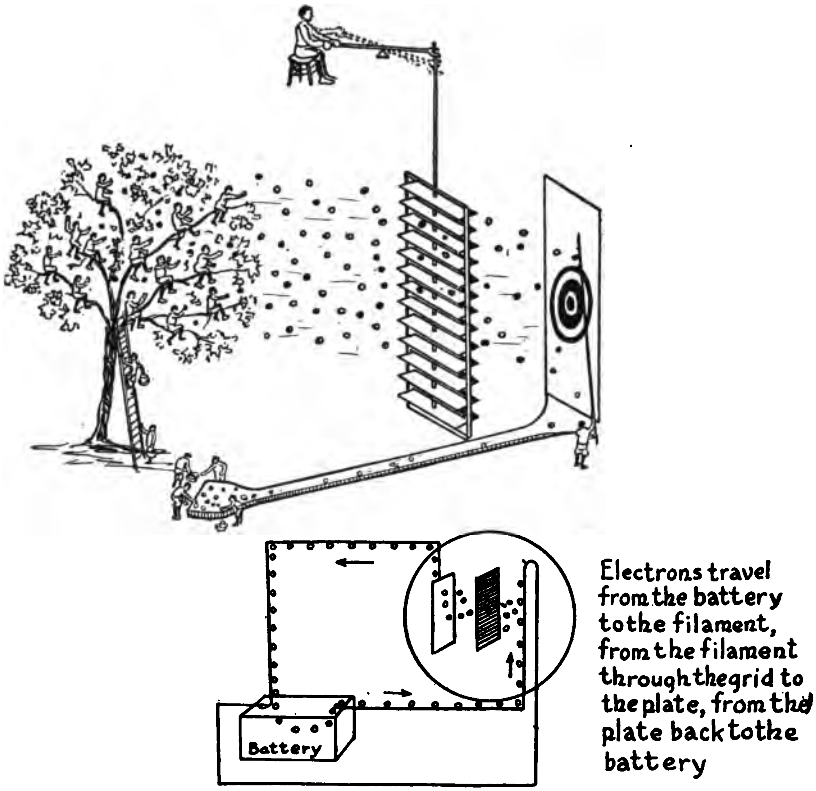


FIG. 53.—The action of a grid in a vacuum bulb can be compared to a shutter which is opened and shut by one boy. The filament can be compared to a tree in which there are a lot of boys trying to throw balls through the shutter to the target which represents the plate. The balls represent the electrons.
The number of balls that get through the shutter depends on the action of the boy controlling the shutter which can be compared to the potential that controls the grid and determines the number of electrons that can pass from the filament to the plate.

the "grid" is inserted. The grid consists of a closely wound spiral, or finely woven screen of wire surrounding the filament, through which the electrons must pass to reach the plate.

Control of Electrons.—As the electrons flow out from the filament they produce a charge in the bulb which tends to keep other electrons from coming out. This charge is called a "**space charge.**" The problem is to reduce the space charge, when more electrons, or a greater current are needed, and to increase the space charge when less current is needed. In other words, how can the stream of electrons flowing from the filament to the plate be controlled?

The answer to this problem was found by Dr. Lee de Forest. If a fine net of wires, which is called a **grid,** is placed close to the filament, the space charge, or rather the effects of the space charge, may be controlled or regulated by varying the voltage or potential impressed on the grid. The grid surrounds the filament; hence stands between the filament and the plate. All the electrons from the filament pass through the interstices of the grid on their way to the plate. When a voltage is impressed on the grid, the amount of electronic flow from the filament to the plate is more or less, according to the amount of voltage on the grid. In other words, the grid determines how many electrons shall pass over the electron bridge between filament and plate.

How the Current is Controlled.—There are really three ways in which the current through the tube is controlled: (A), by making the **grid positive** with **respect** to the **filament,** which reduces the space charge, and causes more electrons to flow from the filament; (B), by making the **grid negative,** which adds to the effect of the electrons in the space, and **increases** the **space charge,** thus tending to **prevent** the **flow of current**) (C), by making any **variation** in the **potential** of the **charge** impressed on the grid, which causes a like variation in the space charge.

In other words, the grid controls the rate at which the electrons reach the plate. When the grid is made positive with respect to the filament, the current passing through the bulb increases. When the grid is made negative the current decreases. The current through the bulb varies with the variation in the amount of the positive and negative quality of the grid. The space between the filament and the plate is full of electrons. Some of these electrons pass through the grid from the filament to the plate; others fall back into the filament from which they have been evaporated; and a few fall on the grid.

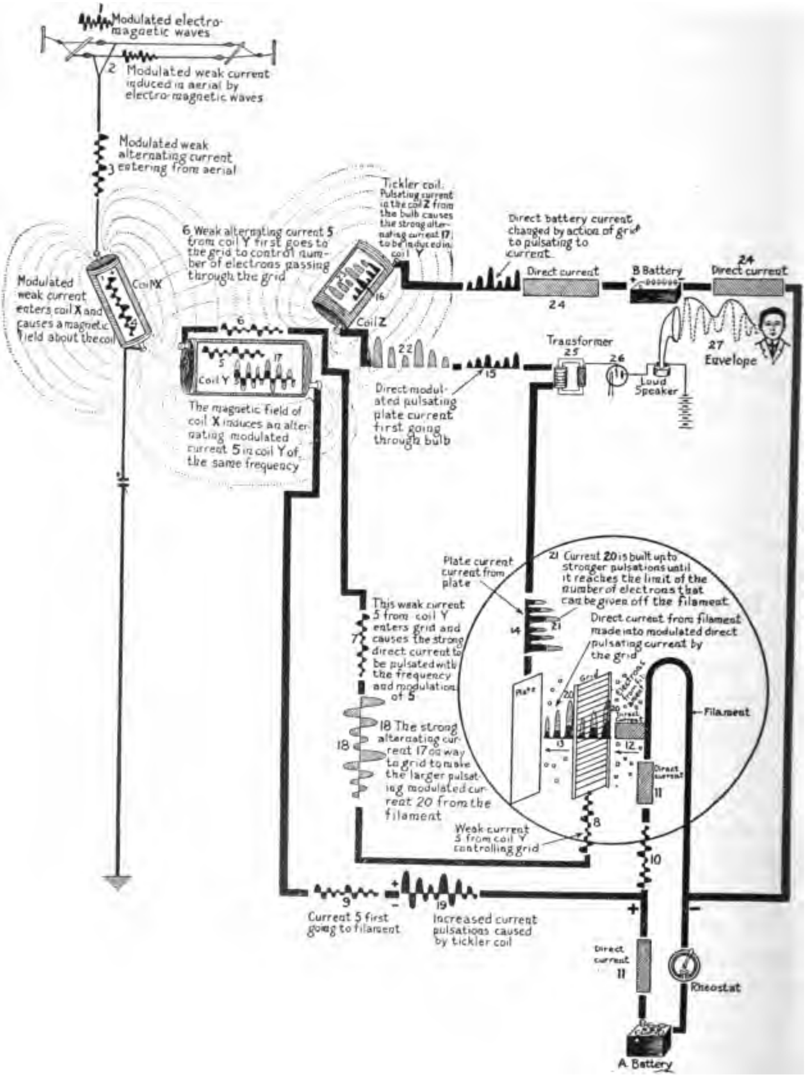

Modulated electro-magnetic waves
2 Modulated weak current induced in aerial by electro-magnetic waves
Modulated weak alternating current 3 entering from aerial
Modulated weak current enters coil X and causes a magnetic field about the coil
Coil X
6 Weak alternating current 5 from coil Y first goes to the grid to control number of electrons passing through the grid
Tickler coil. Pulsating current in the coil Z from the bulb causes the strong alternating current 17 to be induced in coil Y
Coil Z
16
Direct battery current changed by action of grid to pulsating to current
Direct current
24
B Battery
24
Direct current
6
5
17
Coil Y
22
15
Transformer
25
26
Loud Speaker
27
Envelope
The magnetic field of coil X induces an alternating modulated current 5 in coil Y of the same frequency
Direct modulated pulsating plate current first going through bulb
Plate current current from plate
21 Current 20 is built up to stronger pulsations until it reaches the limit of the number of electrons that can be given off the filament
14
21
Direct current from filament made into modulated direct pulsating current by the grid
This weak current 5 from coil Y enters grid and causes the strong direct current to be pulsated with the frequency and modulation of 5
7
Plate
Grid
20
Filament
18 The strong alternating current 17 on way to grid to make the larger pulsating modulated current 20 from the filament
18
13
12
Direct current
11
8
Weak current 5 from coil Y controlling grid
10
9
19
Current 5 first going to filament
Increased current pulsations caused by tickler coil
Direct current
11
Rheostat
A Battery

FIG. 54.

FIG. 54.—Modulated radio waves, **1** (electro-magnetic waves) coming from some broadcasting station induce weak modulated oscillating currents **2** in the aerial. These weaks modulated oscillating currents oscillate in the "lead in" wire **3** and also in the coil **X**, as **4**, the weak modulated oscillating current **4** in the coil **X** causes a magnetic field about the coil **X**. The magnetic field causes a weak modulated oscillating current **5** to be induced in the coil **Y**. This weak oscillating current **5** impresses a weak oscillating voltage represented by **6** on the wire which leads to the grid of the vacuum bulb. The voltage is impressed on the wire **7** to the grid at **8**. Numbers **4**, **5**, **6**, **7**, **8**, represent the same voltage which is induced in the coil **Y** by the weak current **4** from coil **X**.

Current **5** also shown by the dark part in coil **Y** oscillating on the wire, leading to the filament as shown at **9** and entering the filament at **10**. The current then unites with the direct current **11** from the **A** battery. The battery current heats the filament and causes electrons to flow from the filament through the grid to the plate. As the flow of electrons **12** pass off the filament they are made to form a pulsating direct current * **13** shown by the dark portion of the current at the grid because of the voltage **8** which is impressed on the grid. The flow of electrons in the form of a pulsating current **13** goes to the plate and out on the wire as **14**, the dark part of the pulsating direct current **14**. The current * then passes to **15** and enters the **Tickler coil** mark **Z** which is shown by **16**, the dark part in coil **Z**. The tickler coil current **16** causes a magnetic field about the tickler coil which in turn induces a stronger oscillating current than in coil **X** with the same frequency as **3**. This stronger current **18** gives greater control to the grid as shown by **19**.

The greater voltage impressed on the grid by **18** causes a greater flow of electrons from the filament and produces the greater flow of current as shown by the pulsating current **20** which in turn passes to the plate and out on the wire as shown by the figure **21**, the shaded part of the current. This current passes along the wire **22** and enters the Tickler coil **Z** shown by **23**. Current **23** again creates a stronger magnetic field which in turn increases the oscillating current strength in coil **Y** going to the grid and filament. This "feed back" process goes on until the limit of the number of electrons that can be evaporated from the filament has been reached. The direct current **24** from the **B** Battery adds current to the plate current giving it greater strength.

The action of the current in the transformer **25**, in bulb **26** and in the loud speaker is explained in another section.

*Current here means a flow of electrons which flow is opposite to the drection in which direct currents are said to flow.

Saturation.—The number of electrons that can be evaporated from the filament is limited. When the grid or plate voltage increases, the plate current increases, and a greater number of electrons can be taken from the filament to the plate. When the limit is reached, no increase in voltage will carry any more evaporated electrons to the plate. When no more evaporated electrons can be induced to the plate, the plate current is said to be **saturated.**

Filament should never be operated with any more current than is necessary, because tungsten evaporates very rapidly. The plate current should be such as will vary with the slightest change in the potential of the grid.

Action of Vacuum Bulb.—If the plate be made positive by a battery, with respect to the hot filament, the electrons will flow from the filament through the grid, to the plate, along the wires to the battery, and then back again to the filament. By making the grid alternately negative and positive, or varying the strength of its voltage, the number of electrons flowing from the hot filament to the plate can be decreased or increased, since the grid is the valve which permits a certain number of electrons to pass to the plate. Electrons can not pass off the cold plate directly to the filament.

Incoming radio waves produce voltages which are led to the grid, where they control the electronic flow, making it weaker or stronger, according to the strength of the **radio** current. No matter how weak the voltage may be on the grid, it controls the current flow between the filament and plate.

Grid Leak.—Electrons will accumulate on the grid, and finally prevent the grid from becoming active, by giving the grid a negative potential. A little shunt of high resistance is placed across the grid condenser, which permits these electrons to leak back to the filament.

The shunt may be a wire of high resistance that conducts current slowly or even a lead pencil mark on a piece of paper.

Gas Tubes or Soft Tubes.—Tubes of this type contain a small amount of gas. They require careful adjustment, but make excellent detectors, as they are more sensitive than highly evacuated tubes.

Amplification.—When people with poor eyesight try to see, they use glasses to magnify the words. Those who are deaf use ear trumpets.

The moving picture apparatus magnifies the small film picture to the right size. In like manner, the vacuum bulb amplifier is used to magnify the speech or music received by radio.

There are two kinds of amplifiers, one, called the **radio-frequency amplifier,** which amplifies the current before it goes through the detector, and one which amplifies the current after it has gone through the detector. This is called the **audio-frequency amplifier.**

Weak currents control strong currents in a vacuum bulb. This is why the vacuum bulb is a good amplifier.

Vacuum Tubes as Amplifiers.—A vacuum tube may be used as an amplifier when the tube is connected to a battery. The battery will increase the current passing through the vacuum tube, and will make the signal louder as the current passes through the head receiver or a loud-speaking horn.

The vacuum tube is used in another way for transmitting. In receiving, the incoming high-frequency current changes to direct current. For transmitting, we reverse the procedure and use large tubes to change 350, 500, 1000 or 2000 volts direct current into alternating current vibrating at radio frequencies of 50,000 to 2,000,000 per second.

Since minute currents are being used each additional instrument means additional loss of current. Nothing which is not absolutely essential to the circuit should be added to an outfit. Simple sets are easier to handle than complicated ones and less liable to cause trouble by getting out of order.

From the above, it will be seen that the grid of the Vacuum Bulb can be compared to a little boy starting a big locomotive. The boy can turn on the steam which causes the piston of the big engine to draw a heavy freight train. In other words, a small boy can start and control a big power. After the engine is started, it will continue to go because the valves permit the steam to enter first on one side and then on the other side of the piston so that the pistons oscillate back and forth, and make the driving wheel revolve. The valve that admits steam to the steam chamber of the locomotive can be compared to the grid which controls a large flow of currents going through the bulb between the filament and plate making the plate current pulsate, and the current in the grid oscillate. The steam boilers supplying the steam are like the B battery supplying the

electricity. Now, the boy can make the engine pull hard or not, according to the amount he opens or closes the throttle. When the valve or throttle is wide open, greater force is exerted by the steam because a greater amount of steam puffs through into the engine. If the valves are only partly open, a smaller puff of steam gets through. The little boy can be compared to the current coming in. The current controls the grid which permits a large or small flow of current to go from the plate to the filament. As the radio waves are modulated, and the modulations are impressed on the grid they permit a smaller or greater amount of current to pass through the grid, according to their variations. Or in other words the variations in the tiny incoming current with all are reproduced in a large way. There are small or large puffs of electrons from the filament to the plate corresponding to the modulations in the incoming radio waves.

Regenerative Vacuum Tubes.—Some of the tubes are so placed in a receiver as to oscillate continuously, or nearly so. The whole receiving set may be regenerative; that is, the signals or wave-currents received are built up to greater strength. When the set is adjusted so as to have an oscillation condition, these regenerative receivers are said to be *Heterodyne* receivers. When the tubes amplify the sound, and nearly oscillate, the sets are called *non-oscillating regenerative receivers.*

Receiving.—No attempt is made to listen to the radio-frequency waves at all, but only to changes in the wave; that is, **variations** in their width of **swing** or **amplitude.** The diaphragm of the telephone is so constructed as to be sensitive only to the changes in the current.

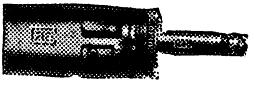


FIG. 55—Telephone Plug.

It responds, not to the high-frequency currents, but to the variations or changes in the amplitude of the incoming waves. The vibration or frequency of the incoming waves is so high, amounting to hundreds of thousands of cycles per second, that the diaphragm would not even start to move from one vibration before the current would change, and it would have a tendency to be pulled in the other direction. But, again, before it could move, the current would change. These changes

occur in alternating currents of high frequency as often as a push and a pull every 1/100,000th of a second. The million cycles of the current can be modified so as to produce 2000, more or less, variations in the million vibrations with thousands of vibrations for each variation. The collection of vibrations produce a wave or current of **audio frequency.**

FIG. 56.—Telephone receivers which are capable of translating electrical vibrations of audio frequency, less than 10,000 cycles per second, into sound waves. The electrical currents cause an iron diaphragm in each receiver to vibrate which in turn produce sound waves. The metal diaphragm is not sensitive to frequencies much over 10,000 cycles per second.

The variations in the radio waves make a wave of audio frequency which is called the **envelope.**

Efficiency of Radio Phone.—The proper radio-phone receiving set will produce loud, clear speech, retaining all voice characteristics. In fact, the individual voice characteristics are retained to a much greater degree than is done by the ordinary telephone, permitting immediate

identification of the speaker, and carrying all inflections of the voice so perfectly that the underlying meanings in a message may be as clearly understood as though the speakers were face to face.

Radio Telephone.—The telephone of the radio receiver consists of a permanent magnet. Around the poles of the magnet is wound a bobbin

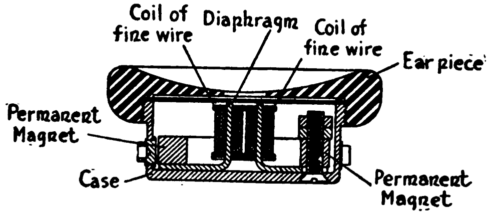


FIG. 57.—A telephone receiver.

of wire. The greater the number of turns in each of these bobbins, the more sensitive will the telephone be. Good telephone sets require many thousands of turns of very fine wire. The number of turns on the bobbin of the telephone determines the relative sensitiveness of the telephone. A metal diaphragm is placed over the poles of the mag-

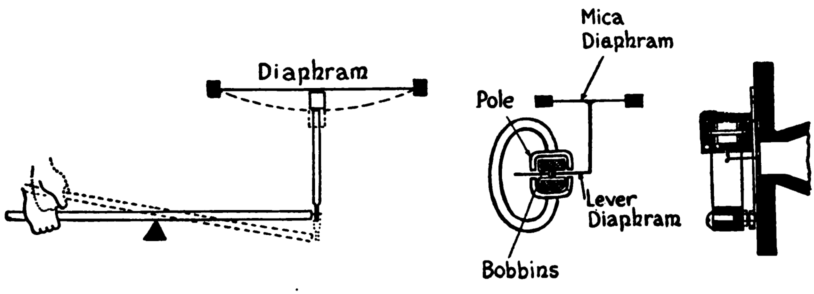


FIG. 58.—The moving parts of a loud speaker.

net and held in place by means of a cover. When a current passes through the coils of the bobbin the magnetic field of poles under the diaphragm will vary according to the variations of the current. Variations in the current cause various kinds of vibrations of the diaphragm which in turn produce sound waves.

For ordinary purposes the telephone described above is satisfactory,

but usually the diaphragm of the ordinary telephone is not sensitive enough for very fine work.

An especially sensitive telephone is manufactured which is more sensitive than the ordinary one and is also better because of the clearness and purity of the sound produced. There is little if any metallic ring in the sounds produced by this receiver.

Loud Speakers.—Loud speakers consist essentially of a powerful permanent magnet, a coil to carry the amplified telephone current, a

FIG. 59.—Loud-speaker receiving set.

FIG. 60.—Another type of loud speaker.

soft iron armature which can move in the field of the magnet according to the variations of currents in the coil, and a flexible diaphragm fastened to the armature by means of a lever, so that its motion may be made greater than the motion of the armature (see Fig. 59). The moving parts of the loud-speaker receiving apparatus are so designed as to produce sound waves of ordinary speech and all vibrations between 200 and 4000 cycles per second which occur in music. Loud speakers usually require large amounts of current.

The megaphone causes sound waves to emerge to a great extent in one direction, hence an ordinary receiver attached to a megaphone or horn will produce louder sounds.

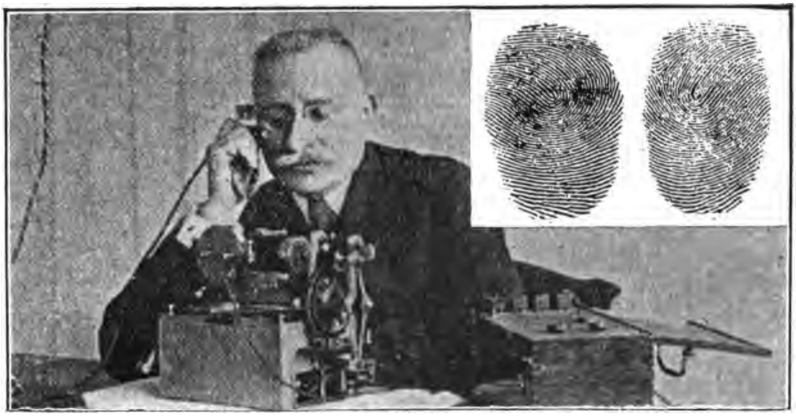
The horn of loud speakers is made of several kinds of material but wood is extensively used and is the best material to produce fine quality of tones.

Loud speakers with the proper " hook up " have made sound waves that have traveled several miles and produced distinct sounds.

Line Radio Communication.—Continuous waves of radio frequency can be guided by wires between the transmitting and receiving stations

Fig. 61.—A photograph sent by wireless.

instead of being radiated through space. Such waves guided on wires can be used for telegraphy or telephony. The conducting lines do not distort the wave form to any extent. Telephoning by use of modulated radio waves guided by wires is called **line radio telephony, carrier frequency telephony, carrier current telephony** and **guide waves telephony** and **wired wireless.** The wave frequency used for line radio communication is usually between 15,000 and 500,000 cycles per second. In



Courtesy of Popular Radio Magazine

FIG. 62.—The telestereograph, a machine that transmits finger prints by radio, consists of a copper cylinder, not unlike that in one of the early Edison phonographs. This cylinder is made to revolve while at the same time a microphone diaphragm (somewhat resembling the sound box of a phonograph and a recording stylus) passes slowly along it in a lengthwise direction. The picture is placed face downward on the copper cylinder after the latter has been covered with shellac; the cylinder is then placed in hot water so that the paper may be removed while the gelatine film of the print is left on it. Some of the gelatine is dissolved but this dissolution is proportional to the lights and shadows of the picture; because of this fact the picture forms a bas relief upon the cylinder with the darker portions higher than the lighter ones, inasmuch as the darker parts are more resistant to the action of the water. The cylinder is then placed in the machine and the apparatus set in motion. The stylus of the microphone presses against the surface of the picture, covering point by point every part of it, thus causing the microphone diaphragm to vibrate to a greater or less extent, according to the height of any given portion of the bas relief. As this diaphgram is exactly like the transmitter of a telephone except that it is moved by the stylus instead of sound waves, it sends impulses of electricity to the receiving apparatus. The path made by the stylus over the revolving cylinder is spiral in form. At the end of the wire is the receiving apparatus. This comprises a cylinder which moves at exactly the same rate of speed as that of the sending apparatus, but instead of the metal needle which formed the transmitting stylus or "translator" the stylus here, whose function it is to impress the sensitive film upon the cylinder, is a fine thread of light. The electrical impulses which are sent over the radio or wire from the gelatine film as just described, set in motion an extremely sensitive galvanometer, in which there is a delicate quartz thread bearing a small mirror. This mirror is twisted slightly in one direction or the other in precise accordance with the movements imported by the stylus to the microphone at the transmitting end. At one side of the mirror is a lamp whose rays are focussed upon it; this pencil of light shifts its position so that it reproduces upon the cylinder the lights and shadows of the original picture.

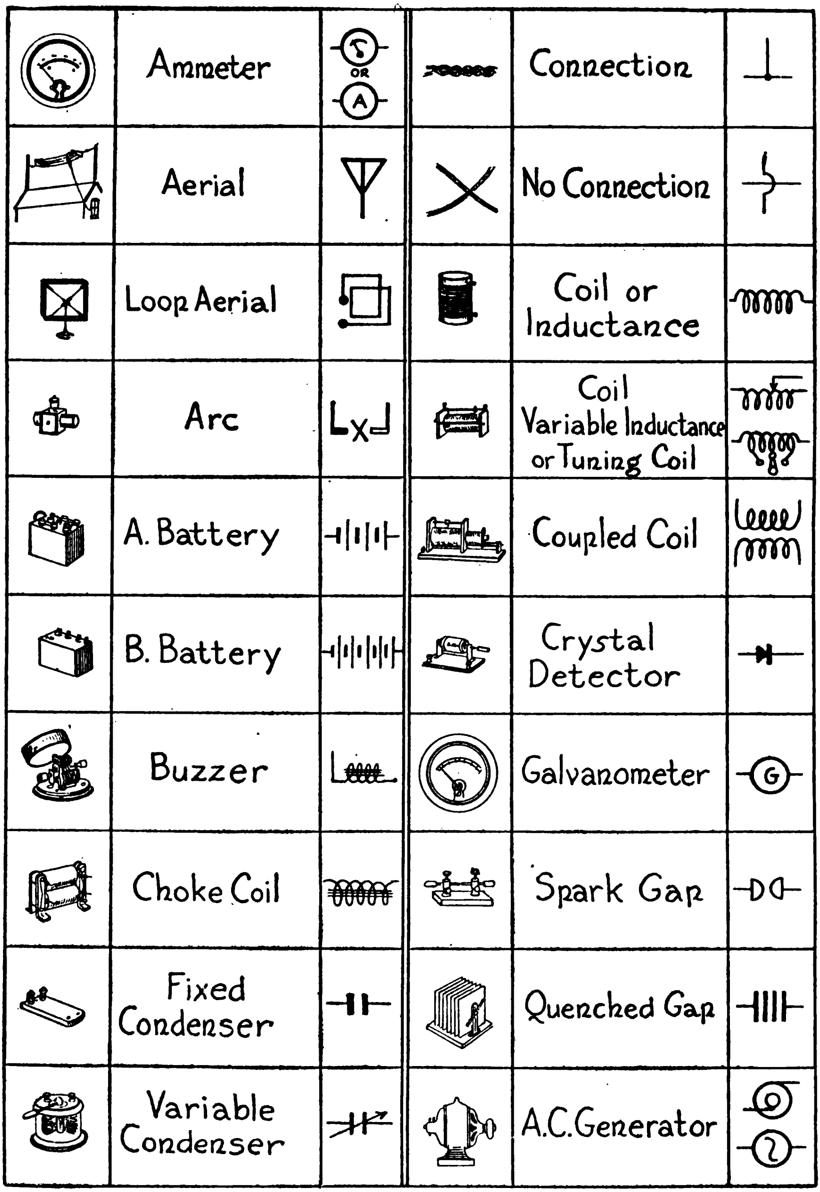


FIG. 63.—Pictures, names, and signs, of parts, used in radio.

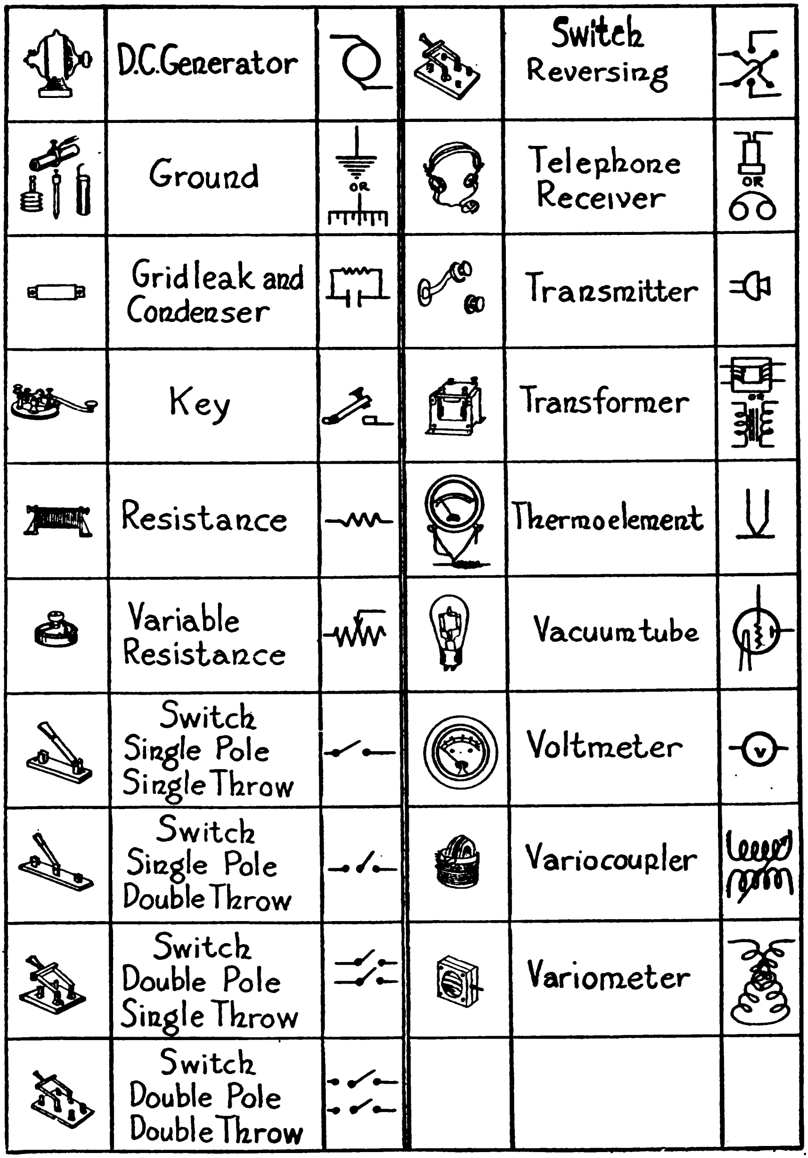


FIG. 64.—Pictures, names, and signs, of parts, used in radio, continued

radio telephoning a number of different conversations can be carried on by a pair of wires at the same time. This is called multiplex telephoning. As many as six conversations have been carried on at the same time over a single pair of wires. Each conversation being trans-

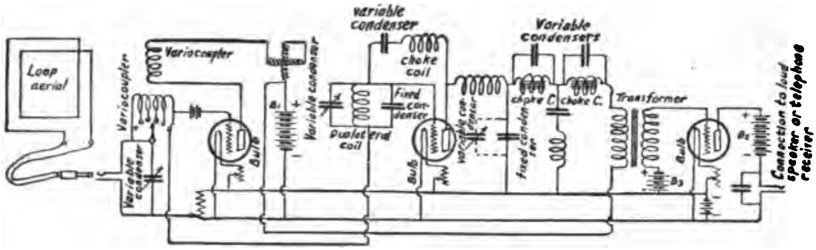


FIG. 65.—A two-stage super regenerator set.*

mitted by radio waves at different frequencies. Usually these frequencies differ from one another by 3000 cycles or more. Trolley wires can be used to conduct radio-frequency current, hence it is possible to

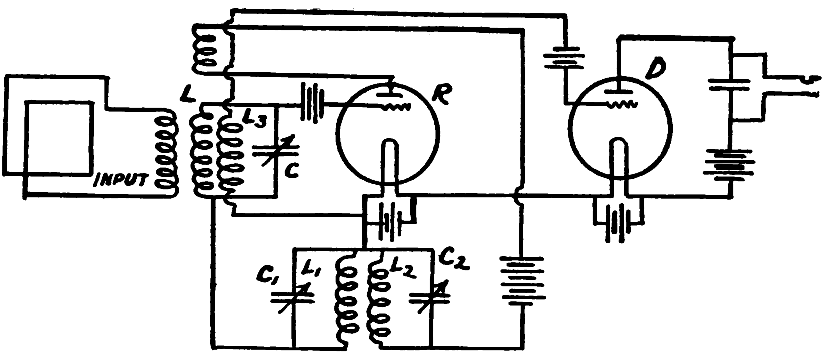


FIG. 66.—One-stage regenerator set.

carry on a conversation from a moving trolley car. Frequencies of less than 3000 cycles apart have been used in conjunction with filters, which filter out interference. Line radio telephoning is often interfered with by high-power radio stations transmitting undamped waves.

* According to Armstrong.

Phantom Current.—Phantom circuits with audio frequency currents are often used so that two pairs of wires are made to transmit three telephone messages. The phantom circuit about the two wires having

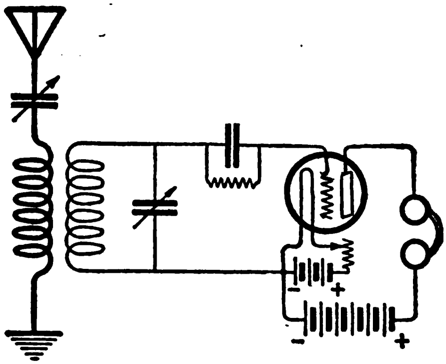


Fig. 67.—Diagram of a one-bulb detector receiving set.

been produced by special methods of wiring, acts like a wire for transmitting a conversation.

Storage Battery

A battery should be kept in a clean, dry place. Keep all small articles, especially metal, out of and away from a battery. The terminals and connections should be coated with vaseline or grease. If the solution is spilled, wipe the battery with waste dipped in ammonia water.

Pure water must be added to all cells regularly and at sufficiently frequent intervals (every two weeks at least) to keep the solution at the proper height. The proper height for the solution is usually given on the instruction sheet or name plate of the battery. In all cases the solution must cover the battery plates. For this purpose, use only distilled water, melted artificial ice, or fresh rain water.

To ascertain the condition of the battery, test the specific gravity (density) of the solution in each cell with a hydrometer or storometer. The hydrometer reading will indicate the condition of the battery as follows: 1275 to 1300 battery fully charged; 1175 to 1200 battery half charged; below 1150 the battery requires charging.

A battery charge is complete when, all cells are gassing (bubbling) freely and evenly, with charging current flowing at the rate given on the instruction plate on the battery. If a hydrometer is not available for battery testing, the condition of the battery may be obtained approximately with a voltmeter. The average storage battery will register 2.2 volts per cell when completely charged and 1.8 volts per cell when completely discharged. Use only direct current (D.C.)

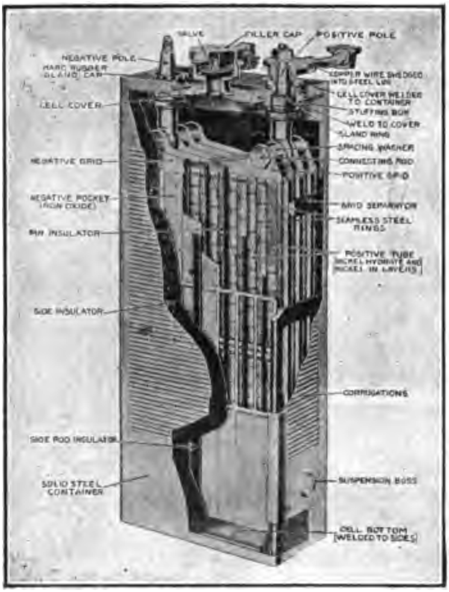


FIG. 68.—A Storage Battery.

Temperatures at which Battery will Freeze at Various Stages of Discharge.

Spec. Grav. of Electrolyte.	Freezing Point Deg. Fahr.
1100	+18
1125	+13
1150	+ 6
1175	− 3
1200	−16
1225	−34
1250	−60
1275	−83

for charging. Limit the current to the proper rate in amperes by connecting a suitable resistance in series with the battery. Incandescent lamps are convenient for this purpose, when direct current is available. When only alternating current supply can be obtained it is necessary to use a rectifier to convert the alternating current into direct current.

When charging a storage battery, connect the positive battery terminal (painted red or marked Pos. P, or Plus) to the positive charging wire and negative to negative. There can be no fixed rule concerning the charging rate of a storage battery, as all manufacturers of batteries make recommendations which apply only to their own product. The charging rate of each battery can generally be found on the name plate or instruction card.

A storage battery is rated according to the number of ampere hours it will discharge at the rate of 1 ampere per hour, For example, a 60 ampere hour storage battery has a capacity of 1 ampere for 60 hours. If the rate of ampere drain is increased to more than 1 ampere, the number of hours required to discharge the battery is decreased in proportion.

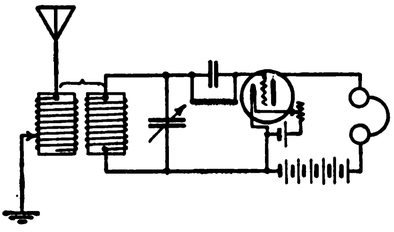


FIG. 69.—An inductively coupled circuit is here used with an audion detector equipped with a grid leak resistance.

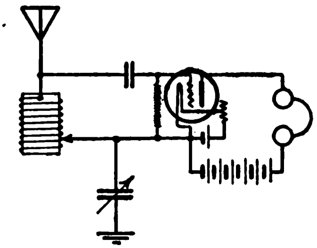


FIG. 70.—A simple circuit, close coupling, with the grid leak connected directly from the grid to the filament of the vacuum tube.

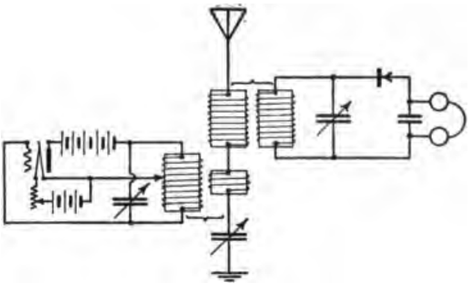
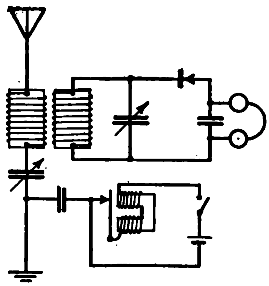


FIG. 71.—An elaborate circuit, using a cyrstal receiver for breaking up continuous waves so as to produce audible signals. A local generator (vacuum tube) of high frequency oscillations is inductively coupled to the primary circuit.

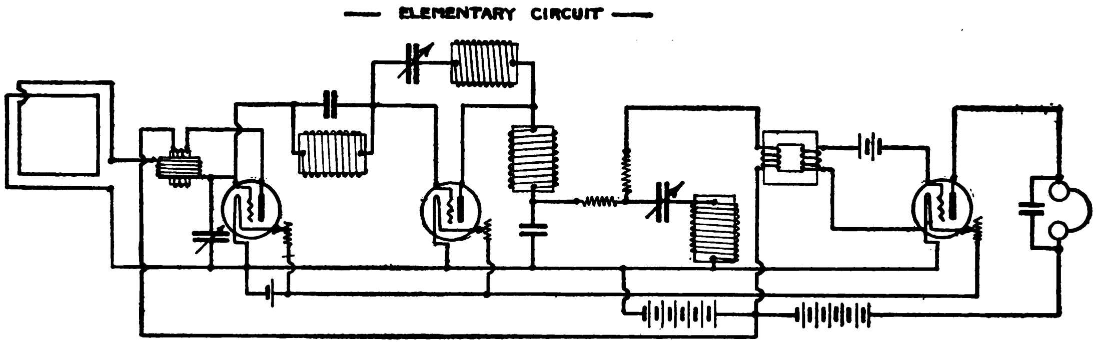


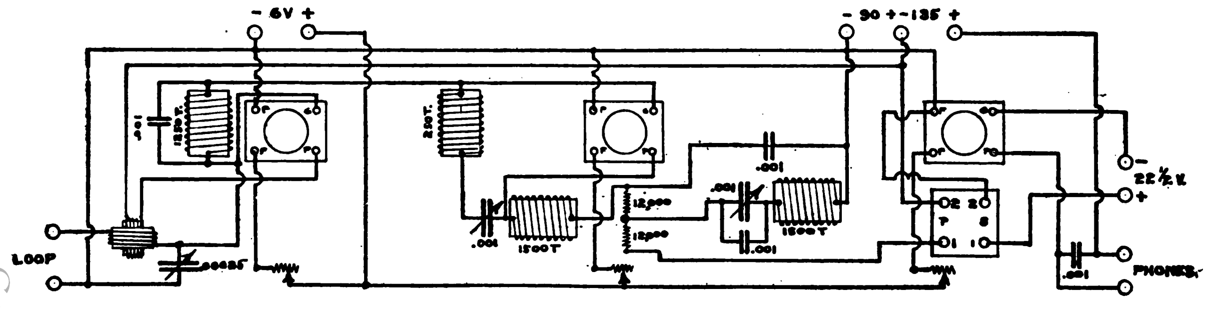
Courtesy of Radio and Model Engineering

FIG. 72.—A buzzer test circuit is here shown connected to a crystal detector receiving outfit. Its purpose is to assist the operator in determining the most sensitive adjustment of the detector.

QUESTIONS

1. Why is it necessary to use step-up transformers in wireless receiving?
2. Why do radio waves produce signals in a receiving circuit?
3. How could a ship at sea with a radio apparatus find its position?
4. What uses up energy in a receiving circuit when signals are being received?
5. What is the difference between a vario-coupler and a variometer?
6. Why are vacuum bulbs more efficient for detectors than crystals?
7. Why does the vacuum bulb detect radio signals?
8. What do you think is meant by " feed back " (see Fig. 47)?





WIRING DIAGRAM AS USED IN THE TYPE 3000 RECEIVER

Fig. 73.—Wiring diagram of a super-regenerative receiving set.*

* An excellent book of 101 (simple and superative regenerative) receiving circuits, by W. H. Bullock, associate editor of The Radio and Model Engineering, New York City, can be obtained from the Sleeper Radio Corporation, publishers.

CHART I

INTERNATIONAL OR CONTINENTAL CODE—PHONETIC METHOD *

USING **TA** FOR DOTS AND **DER** FOR DASHES

Pronounce **TA** very short. It should take three times as long to pronounce **DER.**

A: TA DER
B: DER TA TA TA
C: DER TA DER TA
D: DER TA TA
E: TA
F: TA TA DER TA
G: DER DER TA
H: TA TA TA TA
I: TA TA
J: TA DER DER DER
K: DER TA DER
L: TA DER TA TA
M: DER DER
N: DER TA
O: DER DER DER
P: TA DER DER
Q: DER DER TA DER
R: TA DER TA
S: TA TA TA
T: DER
U: TA TA DER
V: TA TA TA DER
W: TA DER DER
X: DER TA TA DER
Y: DER TA DER DER
Z: DER DER TA TA

Period: TA TA TA TA TA TA
Semicolon: DER TA DER TA DER TA
Comma: TA DER TA DER TA DER
Colon: DER DER DER TA TA TA
Interrogation: TA TA DER DER TA TA
Quotation: TA DAR TA TA DER TA
Exclamation Point: DER DER TA TA DER DER
Apostrophe: TA DER DER DER DER TA
Go Ahead: DER TA DER
Break: DER TA TA TA DER
Hyphen: DER TA TA TA DER
Bar Indicating Fraction: DER TA TA DER TA
Parenthesis: DER TA DER DER TA DER
Inverted Commas: TA DER TA TA DER TA
Quatation Marks: DER TA TA DER TA
Underline: TA TA DER DER TA DER
Double Dash: DER TA TA TA DER
Distress Call: TA TA TA DER DER DER TA TA TA
Attention Call to Precede Every Transmission: DER TA DER TA DER
General Inquiry Call: DER TA DER TA DER DER TA DER
From: DER TA TA TA

GO AHEAD (send the message):	**DER TA DER**
WARNING—HIGH POWER:	**DER DER TA TA DER DER**
QUESTION, PLEASE REPEAT AFTER:	**TA TA DER DER TA TA**
WAIT:	**TA DER TA TA TA**

* New Jersey State Normal School Phonetic Method, 1913–1918.

UNDERSTAND:	**TA TA TA DER TA**
ERROR:	**TA TA TA TA TA TA TA TA**
RECEIVED (OK):	**TA DER TA**
POSITION REPORTED (to precede all position messages):	**DER TA DER TA**
END OF MESSAGE (cross):	**TA DER TA DER TA**
TRANSMISSION FINISHED: **END OF WORK:** **CONCLUSION OF CORRESPONDENCE:**	**TA TA TA DER TA DER**

1: TA DER DER DER DER	**6: DER TA TA TA TA**
2: TA TA DER DER DER	**7: DER DER TA TA TA**
3: TA TA TA DER DER	**8: DER DER DER TA TA**
4: TA TA TA TA DER	**9: DER DER DER DER TA**
5: TA TA TA TA TA	**0: DER DER DER DER DER**

The purpose of the sound charts is to enable the student to get the rhythm of the sounds. A little practice with the chart will be far more effective in learning the code than by attempting to learn dots and dashes. Four charts are given; choose the sounds that will give the best results.

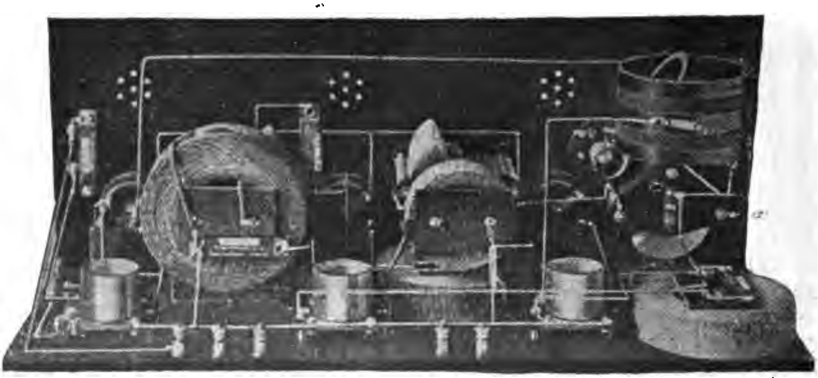


Fig. 74.—Rear view of a super-regenerative receiving set which should assist in the wiring of a set.

CHART II

MORSE CODE—PHONETIC METHOD *

A: TA DER	Z: TA TA TA TA
B: DER TA TA TA	&: TA TA TA TA
C: TA TA TA	
D: DER TA TA	1: TA DER DER TA
E: TA	2: TA TA DER TA TA
F: TA DER TA	3: TA TA TA DER TA
G: DER DER TA	4: TA TA TA TA DER
H: TA TA TA TA	5: DER DER DER
I: TA TA	6: TA TA TA TA TA TA
J: DER TA DER TA	7: DER DER TA TA
K: DER TA DER	8: DER TA TA TA TA
L: DERRRR	9: DER TA TA DER
M: DER DER	0: DERRRR
N: DER TA	
O: TA TA TA TA	Period: TA TA DER DER TA TA
P: TA TA TA TA TA	Comma: TA DER TA DER
Q: TA TA DER TA	Interrogation: DER TA TA DER TA
R: TA TA TA	Dash use: DX
S: TA TA TA	Decimal point spell " dot "
T: DER	Semi-colon use: SI
U: TA TA DER	Exclamation point (!) DER DER TA
V: TA TA TA DER	Fraction bar (/): TA
W: TA DER DER	Paragraph ¶: DER DER DER DER
X: TA DER TA TA	Hyphen: HX
Y: TATA TATA	Parenthesis (begin): PN
	Parenthesis (end): PY
	Quotation (begin): QN
	Quotation (end): QT

DOLLAR SIGN:	SX	UNDERLINE (END):	UT
CAPITALIZED LETTER	CX	COLON AND QUOTATION:	KQ
UNDERLINE (BEGIN):	UX	COLON AND DASH:	KX

* New Jersey State Normal School Phonetic Method, 1913–1918

CHART III

INTERNATIONAL OR CONTINENTAL CODE—PHONETIC METHOD*

USING **TUT** FOR DOTS AND **DER** FOR DASHES

It should take three times as long to say der as it does to say tut.

TUT should be pronounced very short.
DER should be pronounced so as to give three times as much time as was given to TUT.

A: TUT DER
B: DER TUT TUT TUT
C: DER TUT DER TUT
D: DER TUT TUT
E: TUT
F: TUT TUT DER TUT
G: DER DER TUT
H: TUT TUT TUT TUT
I: TUT TUT
J: TUT DER DER DER
K: DER TUT DER
L: TUT DER TUT TUT
M: DER DER
N: DER TUT
O: DER DER DER
P: TUT DER DER TUT
Q: DER DER TUT DER
R: TUT DER TUT
S: TUT TUT TUT
T: DERRR
U: TUT TUT DER
V: TUT TUT TUT DER
W: TUT DER DER
X: DER TUT TUT DER
Y: DER TUT DER DER
Z: DER DER TUT TUT

1: TUT DER DER DER DER
2: TUT TUT DER DER
3: TUT TUT TUT DER DER
4: TUT TUT TUT DER
5: TUT TUT TUT TUT
6: DER TUT TUT TUT
7: DER DER TUT TUT TUT
8: DER DER TUT TUT
9: DER DER DER DER TUT
0: DER DER DER DER DER

* New Jersey State Normal School Phonetic Method, 1913–1918.

CHART IV

INTERNATIONAL OR CONTINENTAL CODE BY THE PHONETIC METHOD *

USING **DIT** for DOTS and **DAH** for DASHES

A: DIT DAH	**1: DIT DAH DAH DAH DAH**
B: DAH DIT DIT DIT	**2: DIT DIT DAH DAH DAH**
C: DAH DIT DAH DIT	**3: DIT DIT DIT DAH DAH**
D: DAH DIT DIT	**4: DIT DIT DIT DIT DAH**
E: DIT	**5: DIT DIT DIT DIT**
F: DIT DIT DAH DIT	**6: DAH DIT DIT DIT DIT**
G: DAH DAH DIT	**7: DAH DAH DIT DIT DIT**
H: DIT DIT DIT DIT	**8: DAH DAH DAH DIT DIT**
I: DIT DIT	**9: DAH DAH DAH DAH DIT**
J: DIT DAH DAH DAH	**0: DAH DAH DAH DAH**
K: DAH DIT DAH	
L: DIT DAH DIT DIT	**L: Period (III): DIT DIT DIT DIT DIT DIT**
M: DAH DAH	**Semi colon: DAH DIT DAH DIT DAH DIT**
N: DAH DIT	**Comma (AAA): DIT DAH DIT DAH DIT DAH**
O: DAH DAH DAH	**Colon: DAH DAH DAH DIT DIT DIT**
P: DIT DAH DAH DIT	**Interrogation: DIT DIT DAH DAH DIT DIT**
Q: DAH DAH DIT DAH	**Quotation: DIT DAH DIT DIT DAH DIT**
R: DIT DAH DIT	**Exclamation: DAH DAH DIT DIT DAH DAH**
S: DIT DIT DIT	**Apostrophe: DIT DAH DAH DAH DAH DIT**
T: DAH	**Go ahead: DAH DIT DAH**
U: DIT DIT DAH	**Break: DAH DIT DIT DIT DAH**
V: DIT DIT DIT DAH	**Hyphen: DAH DIT DIT DIT DAH**
W: DIT DAH DAH	**Bar indicating fraction (/): DAH DIT DIT DAH DIT**
X: DAH DIT DIT DAH	**Parenthesis ( ): DAH DIT DAH DAH DIT DAH**
Y: DAH DIT DAH DAH	**Inverted commas: DIT DAH DIT DIT DAH DIT**
Z: DAH DAH DIT DIT	**Quotation marks: DAH DIT DIT DAH DIT**

Underline: DIT DIT DAH DAH DIT DAH
Double dash: DAH DIT DIT DIT DAH

* New Jersey State Normal School Phonetic Method 1913–1918.—*Newark Evening News.*

Distress call (SOS): DIT DIT DIT DAH DAH DAH DIT DIT DIT
Attention call: DAH DIT DAH DIT DAH
General inquiry call: DIT DAH DAH DIT DAH DAH DIT DAH
From: DAH DIT DIT DIT
Warning (High Power): DAH DAH DIT DIT DAH DAH
Question (Please repeat after): DIT DIT DAH DAH DIT DIT
Wait: DIT DAH DIT DIT DIT
Understand: DIT DIT DIT DAH DIT
Error: DIT DIT DIT DIT DIT DIT DIT DIT
Received (OK): DIT DAH DIT
Position reported: DAH DIT DAH DIT
End of message (cross): DIT DAH DIT DAH DIT
Transmission finished:
End of work:
Conclusion of correspondence:
Signing off:
$\Big\}$ **DIT DIT DIT DAH DIT DAH**

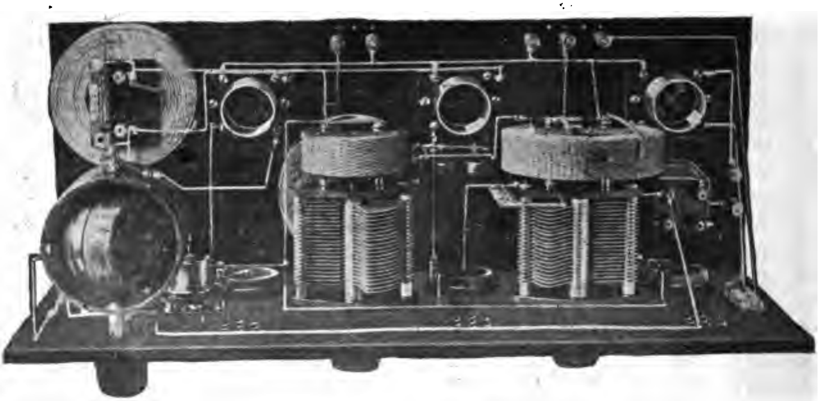


Fig. 75.—Top view, showing details of assembly of a super-regenerative receiving set.

Form 773 a.

DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
RADIO SERVICE

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS
TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •

Ä (German)	• — • —
Á or Å (Spanish-Scandinavian)	• — — • —
CH (German-Spanish)	— — — —
É (French)	• • — • •
Ñ (Spanish)	— — • — —
Ö (German)	— — — •
Ü (German)	• • — —

1	• — — — —
2	• • — — —
3	• • • — —
4	• • • • —
5	• • • • •
6	— • • • •
7	— — • • •
8	— — — • •
9	— — — — •
0	— — — — —

Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
Attention call to precede every transmission	— • — • —
General inquiry call	— • — • — — • —
From (de)	— • • •
Invitation to transmit (go ahead)	— • —
Warning—high power	— — • • — —
Question (please repeat after......)—interrupting long messages	• • — — • •
Wait	• — • • •
Break (Bk.) (double dash)	— • • • —
Understand	• • • — •
Error	• • • • • • • •
Received (O. K.)	• — •
Position report (to precede all position messages)	— • — •
End of each message (cross)	• — • — •
Transmission finished (end of work) (conclusion of correspondence)	• • • — • —

Form 772 a.

DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
RADIO SERVICE

INTERNATIONAL RADIOTELEGRAPHIC CONVENTION
LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION

ABBREVIATION	QUESTION	ANSWER OR NOTICE
PRB	Do you wish to communicate by means of the International Signal Code?	I wish to communicate by means of the International Signal Code.
QRA	What ship or coast station is that?........	This is........
QRB	What is your distance?........	My distance is........
QRC	What is your true bearing?........	My true bearing is........degrees.
QRD	Where are you bound for?........	I am bound for........
QRF	Where are you bound from?........	I am bound from........
QRG	What line do you belong to?........	I belong to the........Line.
QRH	What is your wave length in meters?........	My wave length is........meters.
QRJ	How many words have you to send?........	I have........words to send.
QRK	How do you receive me?........	I am receiving well.
QRL	Are you receiving badly? Shall I send 20? · · · — · for adjustment?........	I am receiving badly. Please send 20. · · · — · for adjustment.
QRM	Are you being interfered with?........	I am being interfered with.
QRN	Are the atmospherics strong?........	Atmospherics are very strong.
QRO	Shall I increase power?........	Increase power.
QRP	Shall I decrease power?........	Decrease power.
QRQ	Shall I send faster?........	Send faster.
QRS	Shall I send slower?........	Send slower.
QRT	Shall I stop sending?........	Stop sending.
QRU	Have you anything for me?........	I have nothing for you.
QRV	Are you ready?........	I am ready. All right now.
QRW	Are you busy?........	I am busy (or: I am busy with......). Please do not interfere.
QRX	Shall I stand by?........	Stand by. I will call you when required.
QRY	When will be my turn?........	Your turn will be No. ....
QRZ	Are my signals weak?........	Your signals are weak.
QSA	Are my signals strong?........	Your signals are strong.
QSB	Is my tone bad?........ / Is my spark bad?........	The tone is bad. / The spark is bad.
QSC	Is my spacing bad?........	Your spacing is bad.
QSD	What is your time?........	My time is........
QSF	Is transmission to be in alternate order or in series?	Transmission will be in alternate order.
QSG	....	Transmission will be in series of 5 messages.
QSH	....	Transmission will be in series of 10 messages.
QSJ	What rate shall I collect for........?........	Collect........
QSK	Is the last radiogram canceled........	The last radiogram is canceled.
QSL	Did you get my receipt?........	Please acknowledge.
QSM	What is your true course?........	My true course is........degrees.
QSN	Are you in communication with land?........	I am not in communication with land.
QSO	Are you in communication with any ship or station (or: with........)?	I am in communication with........ (through........).
QSP	Shall I inform........that you are calling him?	Inform........that I am calling him.
QSQ	Is........calling me?........	You are being called by........
QSR	Will you forward the radiogram?........	I will forward the radiogram.
QST	Have you received the general call?........	General call to all stations.
QSU	Please call me when you have finished (or: at........o'clock)?	Will call when I have finished.
*QSV	Is public correspondence being handled?........	Public correspondence is being handled. Please do not interfere.
QSW	Shall I increase my spark frequency?........	Increase your spark frequency.
QSX	Shall I decrease my spark frequency?........	Decrease your spark frequency.
QSY	Shall I send on a wave length of........meters?	Let us change to the wave length of........meters.
QSZ	....	Send each word twice. I have difficulty in receiving you.
QTA	....	Repeat the last radiogram.
QTE	What is my true bearing?........	Your true bearing is........degrees from........
QTF	What is my position?........	Your position is....latitude....longitude.

*Public correspondence is any radio work, official or private, handled on commercial wave lengths.

When an abbreviation is followed by a mark of interrogation, it refers to the question indicated for that abbreviation.

THE NUCLEUS OF A UNIVERSAL LANGUAGE

These abbreviations are observed internationally; they constitute what is, in effect, the beginning of a world tongue. Every amateur who applies for a license to transmit must pass an examination on this list.

INDEX